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Practical Uses of the Steel Square
Timber Framing, Light and Heavy
Stair-Building and Handrailing

BY

FRED T. HODGSON

Fellow Architectural Institute of Canada, Author of

"Modern Carpentry and Joinery," two volumes; "A Practical Treatise on the Uses of the Steel Square," two volumes; "Heavy and Light Timber Framing Made Easy;" "Common Sense Stair-Building and Hand-Railing;" "Modern Estimator and Contractors' Guide;" "Five Orders of Architecture;" Builders' Architectural Drawing Self-taught;" "The Builders' and Contractors' Guide to Correct Measurements;" "A. B. C. of the Steel Square;" "Practical Bungalows and Cottages for Town and Country;" "Hodgson's Low Cost American Homes;" "The Practical Cabinet Maker and Furniture Designer;" "Easy Lessons in the Art of Practical Wood Carving;" "Concretes, Cements, Mortars, Plasters and Stuccos;" "Practical Bricklaying Self-taught;" "Twentieth Century Bricklayer and Mason's Assistant;" "Practical Stonemasonry Self-taught;" "The Up-to date Hard-wood Finisher."

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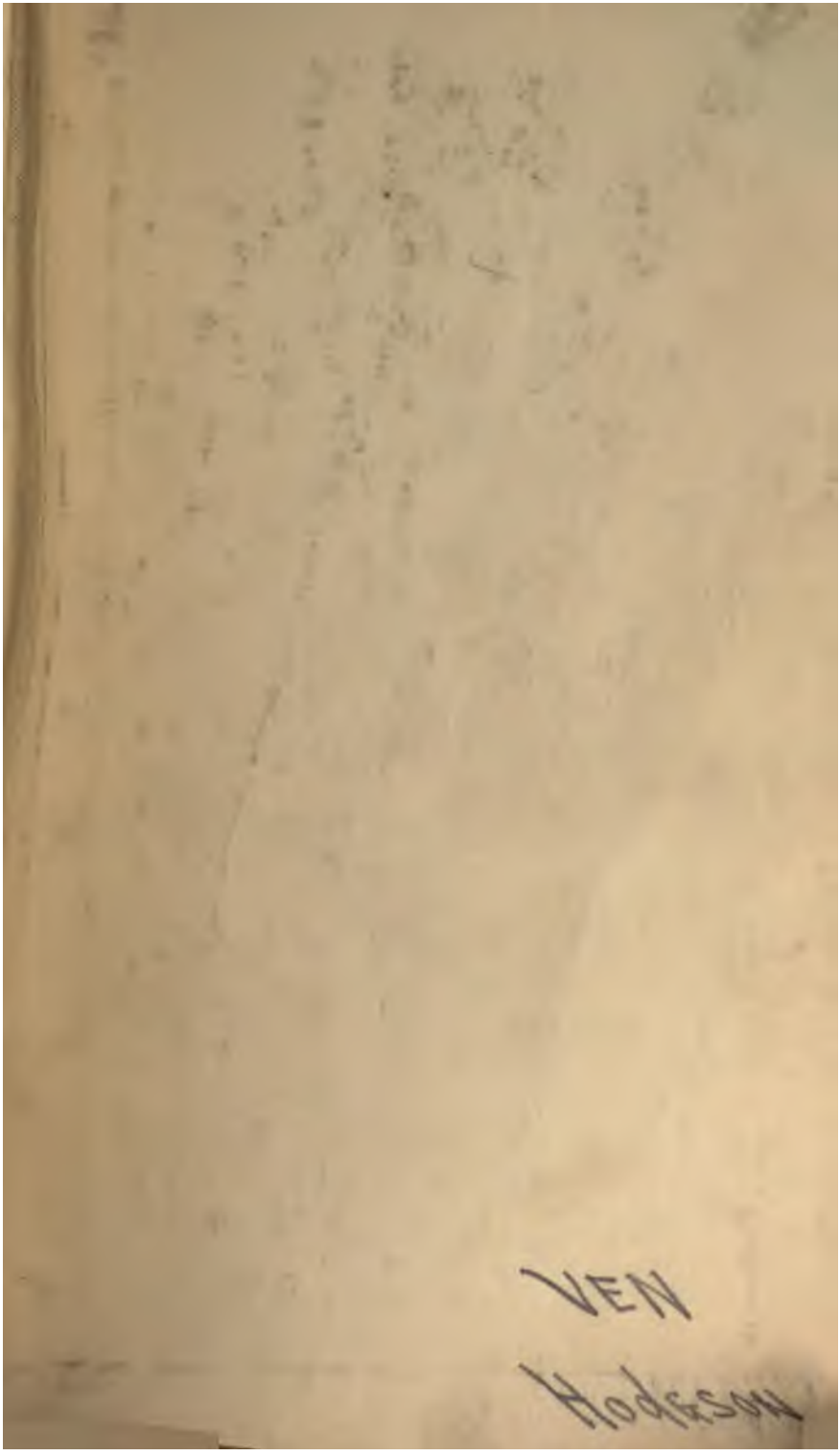
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Hodgson

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PREFACE

ood wine," says Shakespeare, "needs no bush," h of course means that when a thing is good in lf, praise makes it no better. So with a book, if it good, it needs no preface to make it better. The thor of this book flatters himself that the work he as done on it, both as author and compiler, is good; herefore, from his standpoint a preface to it is somewhat a work of supererogation. His opinion regarding the quality of the book may be questioned, but after forty years' experience as a writer of books for builders, all of which have met with success, and during that time over thirty years editor of one of the most popular building journals in America, he feels his opinion, reinforced as it is by thousands of builders and woodworkers throughout the country, should be entitled to some weight. Be that as it may, however, this little book is sent out with a certainty that the one and a half million of men and boys who earn their living by working wood, and fashioning it for useful or ornamental purposes, will appreciate it, because of its main object, which is to lessen their labors by placing before them the quickest and most approved methods of construction.

To say more in this preface is unnecessary and a waste of time for both reader and author.

FRED T. HODGSON.

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MODERN CARPENTRY

PART I

CARPENTER'S GEOMETRY

CHAPTER I

THE CIRCLE

While it is not absolutely necessary that, to become a good mechanic, a man must need be a good scholar or be well advanced in mathematics or geometry, yet, if a man be proficient in these sciences they will be a great help to him in aiding him to accomplish his work with greater speed and more exactness than if he did not know anything about them. This, I think, all will admit. It may be added, however, that a man, the moment he begins active operations in any of the constructional trades, commences, without knowing it, to learn the science of geometry in its rudimentary stages. He wishes to square over a board and employs a steel or other square for this purpose, and, when he scratches or pencils a line across the board, using the [illegible] or the tongue of the square as a guide, while the [illegible] of the blade is against the edge of the board or [illegible]llel with it, he thus solves his first geometrical [illegible]blem, that is, he makes a right angle with the edge [illegible] board. This is one step forward in the path of [illegible]metrical science.

[illegible]e desires to describe a circle, say of eight inches [illegible]meter. He knows instinctively that if he opens his

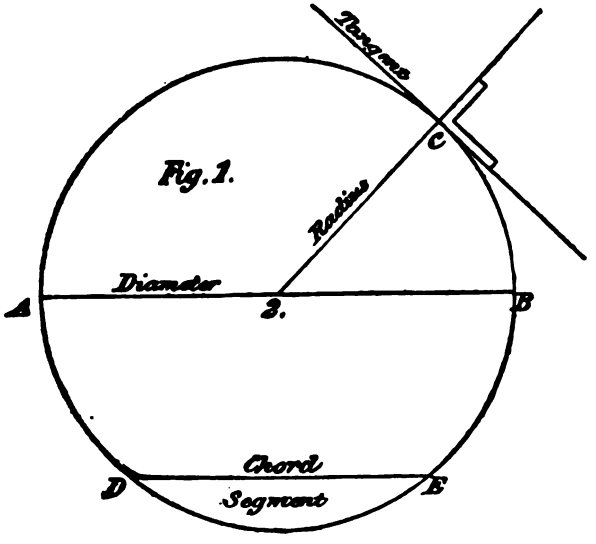
compasses until the points of the legs are four inches apart,—or making the radius four inches—he can, by keeping one point fixed, called a "center," describe a circle with the other leg, the diameter of which will be eight inches. By this process he has solved a second geometrical problem, or at least he has solved it so far that it suits his present purposes. These examples, of course, do not convey to the operator the more subtle qualities of the right angle or the circle, yet they serve, in a practical manner, as assistants in every-day work.

When a man becomes a good workman, it goes without saying that he has also become possessor of a fair amount of practical geometrical knowledge, though he may not be aware of the fact.

The workman who can construct a roof, hipped, gabled, or otherwise, cutting all his material on the ground, has attained an advanced practical knowledge of geometry, though he may never have heard of Euclid or opened a book relating to the science. Some of the best workmen I have met were men who knew nothing of geometry as taught in the books, yet it was no trouble for them to lay out a circular or elliptical stairway, or construct a rail over them, a feat that requires a knowledge of geometry of a high order to properly accomplish.

These few introductory remarks are made with the hope that the reader of this little volume will not be disheartened at the threshold of his trade, because of his lack of knowledge in any branch thereof. To become a good carpenter or a good joiner, a young man must begin at the bottom, and first learn his A, B, C's, and the difficulties that beset him will disappear one after another as his lessons are learned. It

must always be borne in mind, however, that the young fellow who enters a shop, fully equipped with a knowledge of general mathematics and geometry, is in a much better position to solve the work problems that crop up daily, than the one who starts work without such equipment. If, however, the latter fellow be a boy possessed of courage and perseverance, there is no



reason why he should not "catch up"—even overtake—the boy with the initial advantages, for what is then learned will be more apt to be better understood, and more readily applied to the requirements of his work. To assist him in "catching up" with his more favored shopmate, I propose to submit for his benefit a brief description and explanation of what may be termed "Carpenter's Geometry," which will be quite

sufficient if he learn it well, to enable him to execute any work that he may be called upon to perform; and I will do so as clearly and plainly as possible, and in as few words as the instructions can be framed so as to make them intelligible to the student.

The circle shown in Fig. 1 is drawn from the center 2, as shown, and may be said to be a plain figure within a continual curved line, every part of the line being equally distant from the center 2. It is the simplest of all figures to draw. The line AB, which cuts the circumference, is called the diameter, and the line DE is denominated a chord, and the area enclosed within the curved line and the chord is termed a segment. The radius of a circle is a line drawn from the center 2 to the circumference C, and is always one-half the length of the diameter, no matter what that diameter may be. A tangent is a line which touches the circumference at some point and is at right angles with a radial line drawn to that point as shown at C.

The reader should remember these definitions as they will be frequently used when explanations of other figures are made; and it is essential that the learner should memorize both the terms and their significations in order that he may the more readily understand the problems submitted for solution.

It frequently happens that the center of a circle is not visible but must be found in order to complete the circle or form some part of the circumference. The center of any circle may be found as follows: let BHC, Fig. 2, be a chord of the segment H; and BJA a chord enclosing the segment. Bisect or divide in equal parts, the chord BC, at H, and square down from this point to D. Do the same with the chord AJB, squaring over from J to D, then the

point where JD and HD intersect, will be the center of the circle.

This is one of the most important problems for the carpenter in the whole range of geometry as it enables the workman to locate any center, and to draw curves he could not otherwise describe without this or other similar methods. It is by aid of this problem that through any three points not in a straight line, a

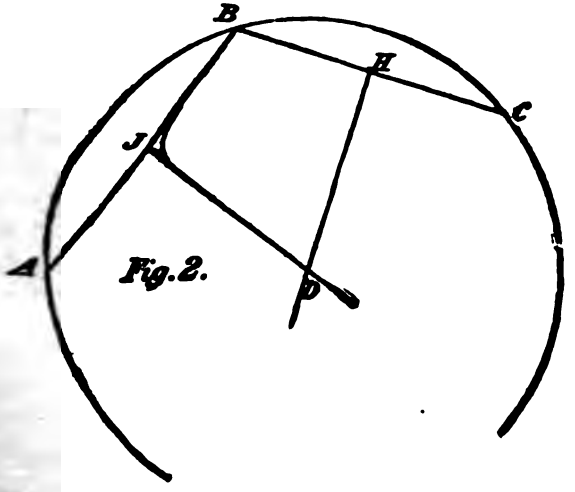


Fig. 2.

circle can be drawn that will pass through each of the three points. Its usefulness will be shown further on as applied to laying out segmental or curved top window, door and other frames and sashes, and the learner should thoroughly master this problem before stepping further, as a full knowledge of it will assist him very materially in understanding other problems.

The circumference of every circle is measured by being supposed to be divided into 360 equal parts, led *degrees*; each degree containing 60 *minutes*, a

smaller division, and each minute into 60 seconds, a still smaller division. Degrees, minutes, and seconds are written thus: 45° 15′ 30″, which is read, forty-five degrees, fifteen minutes, and thirty seconds. This, I think, will be quite clear to the reader. Arcs are measured by the number of degrees which they contain: thus, in Fig. 3, the arc AE, which contains 90°, is called a quadrant, or the quarter of a circumference, because

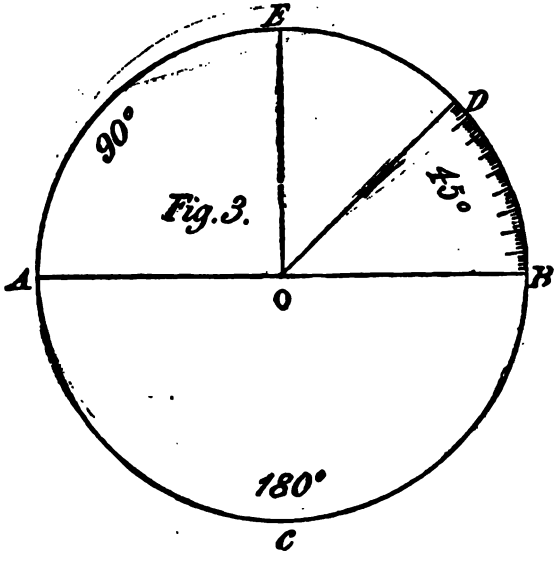


Fig. 3.

90° is one quarter of 360°, and the arc ABC which contains 180°, is a semi-circumference. Every angle is also measured by degrees, the degrees being reckoned on an arc included between its sides; described from the vertex of the angle as a center, as the point O, Fig. 3; thus, AOE contains 90°; and the angle BOD, which is half a right angle, is called an angle of 45°, which is

the number it contains, as will be seen by counting off the spaces as shown by the divisions on the curved line BD. These rules hold good, no matter what may be the diameter of the circle. If large, the divisions are large; if small, the divisions are small, but the manner of reckoning is always the same.

One of the qualities of the circle is, that when divided in two by a diameter, making two semicircles, any chord starting at the extremity of such a diameter, as at A or B, Fig. 4, and cutting the circumference at any point, as at C, D or E, a line drawn from this

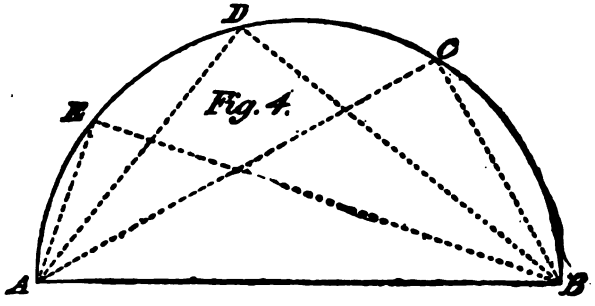


Fig. 4.

point to the other extremity of the diameter, will form a right angle—or be square with the first chord, as is shown by the dotted lines BCA, BDA, and BEA. This is something to be remembered, as the problem will be found useful on many occasions.

The diagram shown at Fig. 5 represents a hexagon within a circle. This is obtained by stepping around the circumference, with the radius of the circle on the compasses, six times, which divides the circumference into six equal parts; then draw lines to each point, which, when completed, will form a hexagon, a six-sided figure. By drawing lines from the points obtained in the circumference to the center, we get a

three-sided figure, which is called an equilateral triangle, that is, a triangle having all its sides equal in

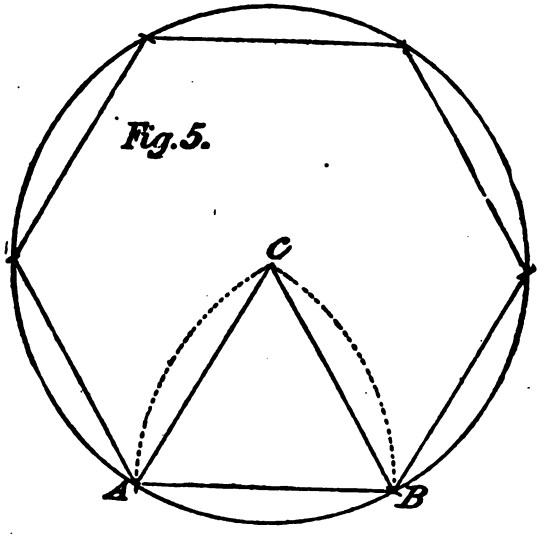


Fig. 5.

length; as AB, AC and BC. The dotted lines show how an equilateral triangle may be produced on a straight line if necessary.

The diagram shown at Fig. 6 illustrates the method of trisecting a right angle or quadrant into three equal parts. Let A be a center, and with the same radius intersect at E, thus the quadrant or right angle is divided into three equal parts.

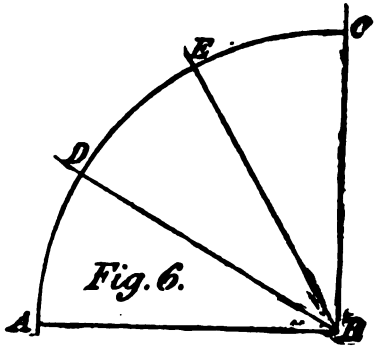


Fig. 6.

If we wish to get the length of a straight line that shall equal the circumference of a circle or part of circle or quadrant, we can do so by proceeding as follows: Suppose Fig. 7 to represent half of the circle, as at ABC; then draw the chord BC, divide it at P, join it at A; then four times PA is equal to the circumference of a circle whose diameter is AC, or equal to the curve CB.

To divide the quadrant AB into any number of equal parts, say thirteen, we simply lay on a rule and make the distance from A to R measure three and one-

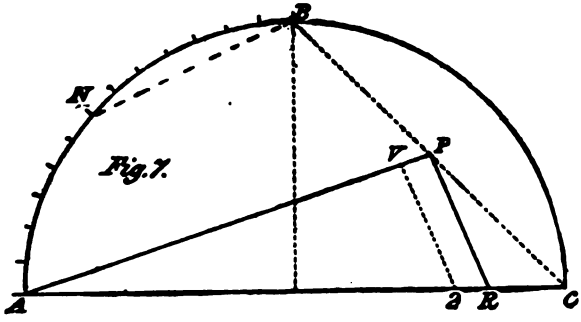


Fig. 7.

fourth inches, which are thirteen quarters or parts on the rule; make R2 equal one-fourth of an inch; join RP; draw from 2 parallel with RP, cutting at V; now take PV in the dividers and set off from A on the circle thirteen parts, which end at B, each part being equal to PV, and the problem is solved. The "stretchout" or length of any curved line in the circle can then be obtained by breaking it into segments by chords, as shown at BN.

I have shown in Fig. 5, how to construct an equilateral triangle by the use of the compasses. I give at

Fig 8 a practical example of how this figure, in connection with circles, may be employed in describing a figure known as the trefoil, a figure made much use of in the construction of church or other Gothic work and for windows and carvings on doors and panelings. Each corner of the triangle, as ABC, is a center from which are described the curves shown within the outer circles. The latter curves are struck from the center

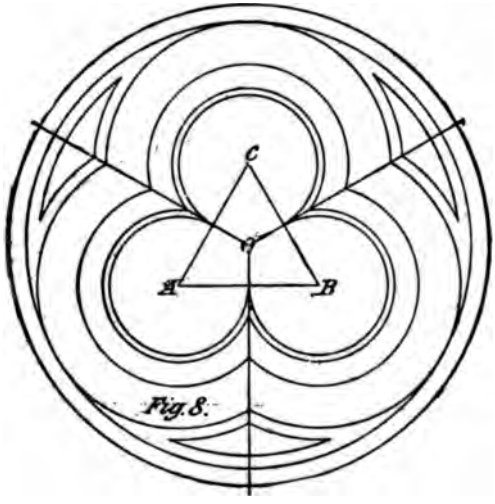


Fig. 8.

O, which is found by dividing the sides of the equilateral triangle and squaring down until the lines cross at O. The joint lines shown are the proper ones to be made use of by the carpenter when executing his work. The construction of this figure is quite simple and easy to understand, so that any one knowing how to handle a rule and compass should be able to construct it after a few minutes' thought. This figure is the key to most Gothic ornamentation, and is worth mastering.

...wn as shown until the lines intersect at ...is point O is the center of the circle. ...happens that it is not possible to find a ... a center, because of the diameter being ... segmental windows and doors of large To overcome this difficulty a method

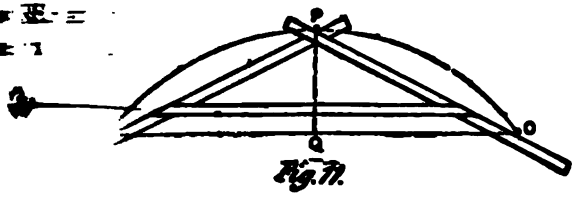


Fig. 11.

...levised by which the curve may be correctly ...ailing three wooden strips together so as to ...ngle, as shown in Fig. 11. Suppose NO to ...d or width of frame, and QP the height of ...suring from the springing lines N and O; ... pins at O and N, keep the triangle close ...ils, and place a pencil at P, then slide ...inst the pins or nails while sliding, and ...scribe the necessary curve. The ... should be several inches longer ... that when the pencil P arrives at ... still rest against the pins.

metically or geometrically, though for all practical purposes the methods given are quite near enough. No method, however, that is given geometrically is so simple, so convenient and so accurate as the arithmetical one, which I give herewith. If we multiply the diameter of a circle by 3.1416, the product will give the length of the circumference, very nearly. These figures are based on the fact that a circle whose diameter is 1—say one yard, one foot, or one inch—will have a circumference of nearly 3.1416 times the diameter.

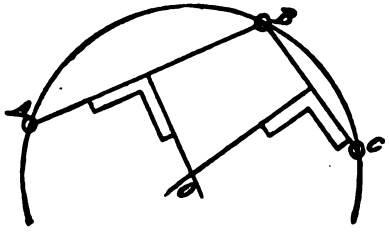


Fig. 10.

With the exception of the formation of mouldings, and ornamentation where the circle and its parts take a prominent part, I have submitted nearly all concerning the figure, the everyday carpenter will be called upon to employ, and when I approach the chapter on Practical Carpentry later on, I will try and show how to use the knowledge now given.

Before leaving the subject, however, it may be as well to show how a curve, having any reasonable radius, may be obtained—practically—if but three points in the circumference are available; as referred to in the explanation given of Fig. 5. Let us suppose there are three points given in the circumference of a circle, as ABC, Fig. 10, then the center of such circle can be found by connecting the points AB and BC by straight lines as shown, and by dividing these lines

and squaring down as shown until the lines intersect at O as shown This point O is the center of the circle.

It frequently happens that it is not possible to find a place to locate a center, because of the diameter being so great, as in segmental windows and doors of large dimensions. To overcome this difficulty a method

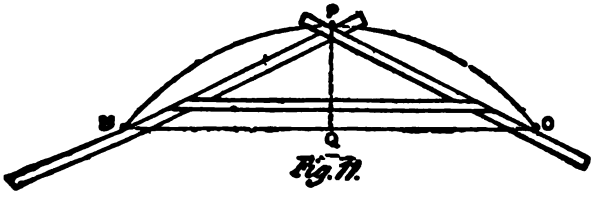


Fig. 11.

has been devised by which the curve may be correctly drawn by nailing three wooden strips together so as to form a triangle, as shown in Fig. 11. Suppose NO to be the chord or width of frame, and QP the height of segment, measuring from the springing lines N and O; drive nails or pins at O and N, keep the triangle close against the nails, and place a pencil at P, then slide the triangle against the pins or nails while sliding, and the pencil will describe the necessary curve. The arms of the triangle should be several inches longer than the line NO, so that when the pencil P arrives at N or O, the arms will still rest against the pins.

CHAPTER II

POLYGONS

A polygon is a figure that is bounded by any number of straight lines; three lines being the least that can be employed in surrounding any figure, as a triangle, Fig. 1.

A polygon having three sides is called a trigon; it is also called an equilateral triangle. A polygon of four sides is call a tetragon; it is also called a square and an equilateral rectangle. A polygon of five sides is a pentagon. A polygon of six sides is a hexagon. A polygon of seven sides is called a heptagon. A polygon of eight sides is called an octagon. A polygon of nine sides is called a nonagon. A polygon of ten sides is called a decagon. A polygon of eleven sides is called an undecagon. And a polygon of twelve sides is called a dodecagon.

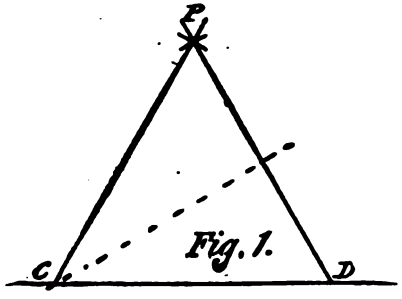


Fig. 1.

There are regular and irregular polygons. Those having equal sides are regular; those having unequal sides are irregular. Polygons having more than twelve sides are known among carpenters by being denominated as a polygon having "so many sides," as a "polygon with fourteen sides," and so on.

Polygons are often made use of in carpenter work, particularly in the formation of bay-windows, oriels, towers, spires, and similar work; particularly is this the case with the hexagon and the octagon; but the most used is the equilateral rectangle, or square; therefore it is essential that the carpenter should know considerable regarding these figures, both as to their qualities and their construction.

The polygon having the least lines is the trigon, a three-sided figure. This is constructed as follows: Let CD, Fig. 1, be any given line, and the distance CD the length of the side required. Then with one leg of the compass on D as a center, and the other on C, describe the arc shown at P. Then with C as a center, describe another arc at P, cutting the first arc. From this point of intersection draw the lines PD and PC, and the figure is complete. To get the miter joint of this figure, divide one side into two equal parts, and from the point obtained draw a line through opposite angle as shown by the dotted line, and this line will be the line of joint at C, or for any of the other angles.

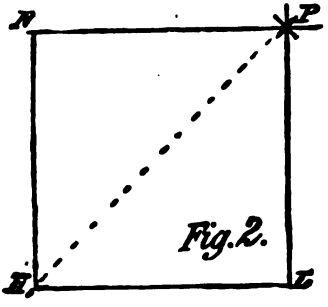


Fig. 2.

The square, or equilateral rectangle, Fig. 2, may be obtained by a number of methods, many of which will suggest themselves to the reader. I give one method that may prove suggestive. Suppose two sides of a square are given, LHN, the other sides are found by taking HL as radius, and with LN for centers make the intersection in P, draw LP and NP, which com-

pletes the figure. The miter for the joints of a figure of this kind is an angle of 45°, or the regular miter. The dotted line shows the line of "cut" or miter.

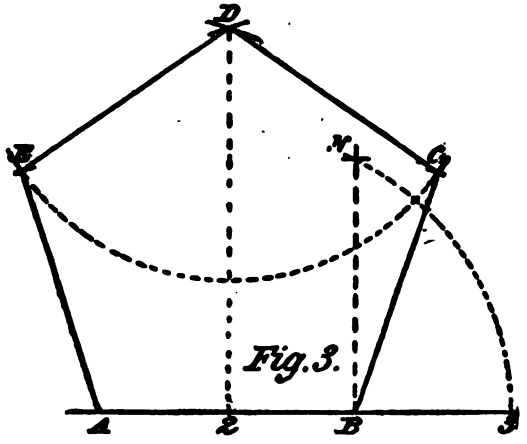


Fig. 3.

To construct a pentagon we proceed as follows: Let AB, Fig. 3, be a given line and spaced off to the length of one side of the figure required; divide this line into two equal parts. From B square up a line; make BN equal to AB, strike an arc 3N as shown by the dotted lines, with 2 as a center and N as a radius, cutting the given line at 3. Take A3 for radius; from A and B as centers, make the intersection in D; from D, with a

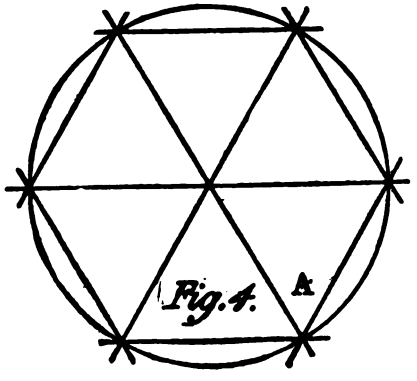


Fig. 4.

radius equal to AB, strike an arc; with the same radius and A and B as centers, intersect the arc in EC. By joining these points the pentagon is formed. The cut, or angle of joints, is found by raising a line from 2 and cutting D, as shown by the dotted line.

The hexagon, a six-sided figure shown at Fig. 4, is one of the simplest to construct. A quick method is described in Chapter I, when dealing with circles, but I show the method of construction in order to be certain that the student may be the better equipped to deal with the figure. Take the length of one side of the figure on compasses; make this length the radius of a circle, thus describe a circle as shown. Start from any point, as at A, and step around the circumference of the circle with the radius of it, and the points from which to draw the sides are found, as the radius of any circle will divide the circumference of that circle into six equal parts.

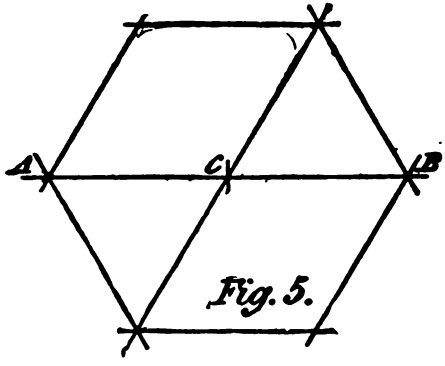


Fig. 5.

This figure may be drawn without first making a circle if necessary. Set off two equal parts, ABC, Fig. 5, making three centers; from each, with radius AC, make the intersection as shown, through which draw straight lines, and a hexagon is formed. The miter joint follows either of the straight lines passing through the center, the bevel indicating the proper angle.

The construction of a heptagon or seven-sided figure may be accomplished as follows: Let AB, Fig. 6, be a given line, and the distance AB the length of the side of the figure. Divide at K, square up from this point, then take AB for radius and B as a center; intersect the line from K at L; with same radius and A as center, draw the curve 2, 3; then take KL as radius, and from 2 as a center, intersect the circle at 3; draw from it to B, cutting at N, through which point draw from A; make AD equal B3; join A3 and BD; draw from 3 parallel with AD; draw from B through L, cutting at C; join it and A; draw from 3 parallel with AC; make 3H equal AB, and CE equal ND; join ED; draw from H parallel with 3C, cutting at F, join this line and E, which completes the heptagon. It is not often this figure is used in carpentry, though I have sometimes employed it in constructing bay windows and dormers, using the four sides, 3H, HF, FE, and ED. This makes a bold front, and serves well in a conservatory or other similar place.

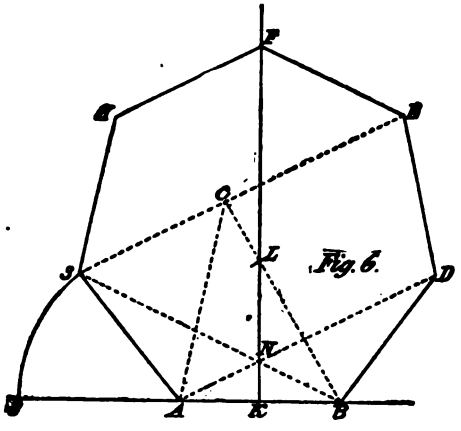


Fig. 6.

It is proper that the reader should know how to construct this figure, as it serves as an exercise, and illustrates a principle of drawing by parallels, a knowledge of which would be found invaluable to the ambi-

tious young carpenter, who desires to become, not only a good workman, but a good draftsman as well.

The octagon or eight-sided figure claims rank next to the square and circle, in point of usefulness to the general carpenter, owing partly to its symmetry of form and its simplicity of construction. There are a great number of methods of constructing this figure, but I will give only a few of the simplest, and the ones most likely to be readily understood by the ordinary workman.

One of the simplest methods of forming an octagon is shown at Fig. 7, where the corners of the square are used as centers, and to the center A of the square for radius. Parts of a circle are then drawn and continued until the boundary lines are cut. Thru the points found draw diagonal lines from the corner as shown, and the figure will be a complete octagon, having all its sides of equal length.

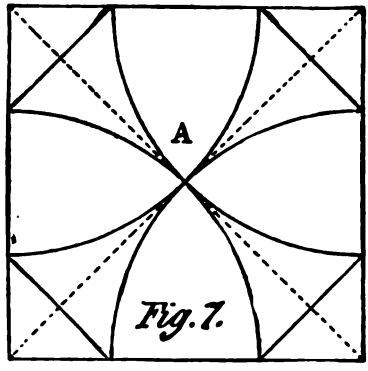


Fig. 7.

The method of obtaining the joint cut or miter for the octagon is shown at Fig. 8, where the angle ABC, bisected into two equal angles by the following means: From B. with any radius, strike an arc, giving A and C as centers, from which, with any radius, make intersection, as shown, and through it from B, draw a line, and the proper angle for the cut is obtained, the dotted line being the angle sought. By this method

of bisecting an angle, no matter how obtuse or acute it may be, the miter joint or cut may be obtained. This is a very useful problem, as it is often called into requisition for cutting mouldings in panels and other work, where the angles are not square, as in stair spandrils and raking wainscot.

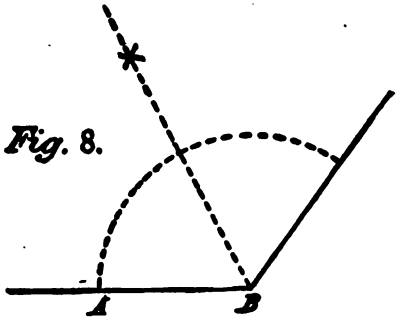


Fig. 8.

To construct an octagon when the length of one of its sides is given, as AB, Fig. 9, square up the two lines, AN, BF, then

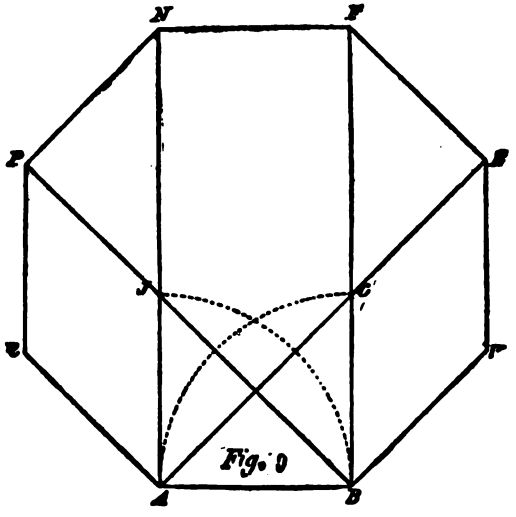
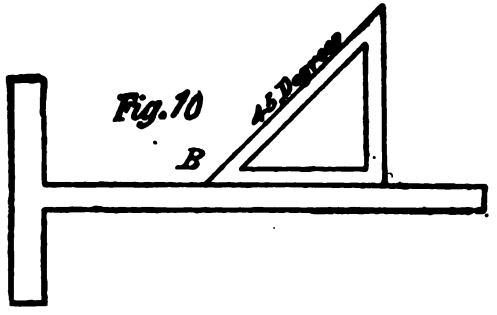


Fig. 9

take AB as radius with A and B as centers, and draw the arcs, cutting the two lines at C and J;

draw from AB, through CJ, and again from A draw parallel with BJ; then draw from B parallel with AC; make BV and CF equal AB; join EV; make CF equal CA; square over FN; join FE; draw NP parallel with AC, then join PR, and the figure is complete.



As the sides of all regular octagons are at an angle of 45° with each other, it follows that an octagon may be readily constructed by making use of a set square having its third side to correspond with an angle of 45°, for by extending the line AB, and laying the set square on the line with one point at B, as shown in Fig. 10, the line BV, Fig. 9, can be drawn, and when made the same length as BV, the process can be repeated to VE; and so on until all the points have been connected.

Suppose we have a square stick of timber 12 x 12 inches, and any length, and we wish to make it an octagon; we will first be obliged to find the gauge points so as to mark the stick, to snap a chalk line on it so as to tell how much of the corners must be removed in order to give to the stick eight sides of equal width. We do this as follows: Make a drawing the size of a

section ot the timber, that is, twelve inches square, then draw a line from corner to corner as AB, Fig. 11, and make AC equal in length to AD, which is twelve inches; square over from C to K; set your gauge to BK, and run your lines to this gauge, and remove the corners off to lines, and the stick will then be an octagon having eight equal sides.

There are a number of other methods of finding the

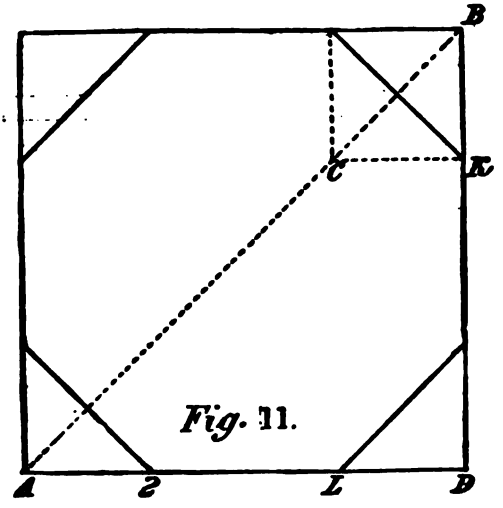


Fig. 11.

gauge points, some of which I may describe further on, but I think I have dwelt long enough on polygons to enable the reader to lay off all the examples given. The polygons not described are so seldom made use of in carpentry, that no authority that I am aware of describes them when writing for the practical workman; though in nearly all works on theoretical geom-

etry the figures are given with all their qualities. If the solution of any of the problems offered in this work requires a description and explanation of polygons with a greater number of sides than eight, such explanation will be given.

CHAPTER III

SOME STRAIGHT LINE SOLUTIONS

The greatest number of difficult problems in carpentry are susceptible of solution by the use of straight lines and a proper application of the steel square, and in this chapter I will endeavor to show the reader how some of the problems may be solved, though it is not intended to offer a treatise on the subject of the utility of the steel square, as that subject has been treated at length in other works, and another and exhaustive work is now in preparation; but it is thought no work on carpentry can be complete without, at least, showing some of the solutions that may be accomplished by the proper use of this wonderful instrument, and this will be done as we proceed.

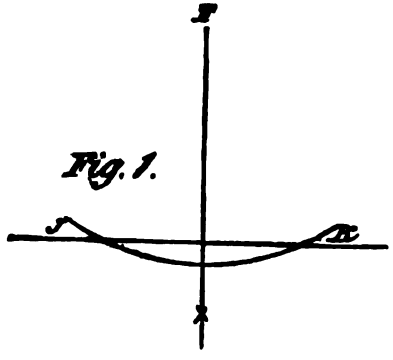


Fig. 1.

One of the most useful problems is one that enables us to make a perpendicular line on any given straight line without the aid of a square. This is obtained as follows: Let JK, Fig. 1, be the given straight line, and make F any point in the square or perpendicular line required. From F with any radius, strike the arc

cutting in JK; with these points as centers, and any radius greater than half JK, make intersection as shown, and from this point draw a line to F, and this line is the perpendicular required. Foundations, and other works on a large scale are often "squared" or laid out by this method, or by another, which I will submit later.

In a previous illustration I showed how to bisect an angle by using the compasses and straight lines, so as to obtain the proper joints or miters for the angles. At Fig. 2, I show how this may be done by the aid of the steel square alone, as follows: The angle is obtuse, and may be that of an octagon or pentagon or other polygon. Mark any two points on the angle, as DN, equally distant from the point of angle L; apply the steel square as shown, keeping the distance EN and ED the same, then a line running through the angle L and the point of the square E will be the line sought.

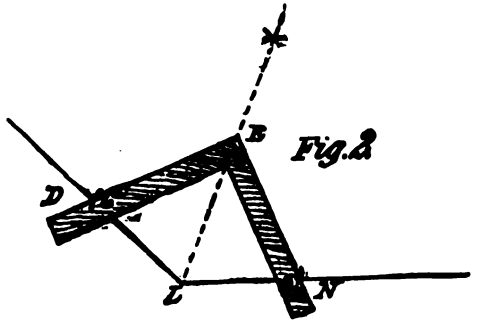


Fig. 2

To bisect an acute angle by the same method, proceed as follows: Mark any two points AC, Fig. 3, equally distant from B; apply the steel square as shown, keeping its sides on AC; then the distance on each side of the square being equal from the corner gives it for a point, through which draw a line from B, and the angle is divided. Both angles shown are divided by the same method, making the intersection

in P the center of the triangle. The main thing to be considered in this solution is to have the distances A and C equal from the point B; also an equal distance from the point or toe of the square to the points of contact C and A on the boundary lines.

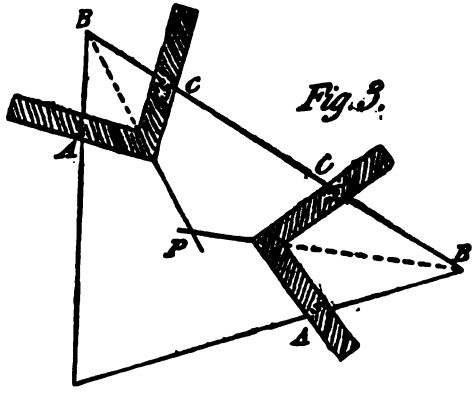


Fig. 3.

A repetition of the same method of bisecting angles, under other conditions, is shown at Fig. 4. The process is just the same, and the

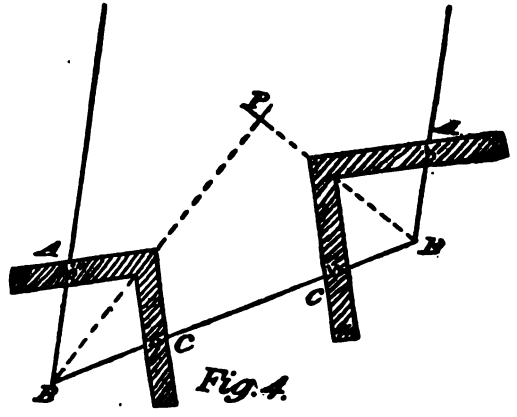


Fig. 4.

reference letters are also the same, so any further explanation is unnecessary.

To get a correct miter cut, or, in other words, an angle of 45°, on a board, make either of the points A or C, Fig. 5, the starting point for the miter, on the edge of the board, then apply the square as shown, keeping the figure 12" at A or C, as the case may be, with the figure 12" on the other blade of the square on the edge of the board as shown; then the slopes on the edge of the square from A to B and C to B, will form angles of 45° with the base line AC. This problem is useful from many points of view, and will often suggest itself to the workman in his daily labor.

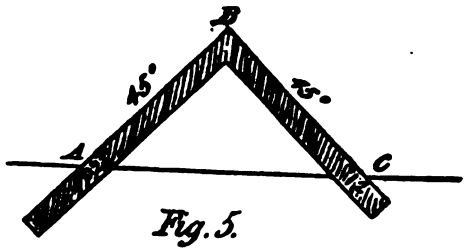


Fig. 5.

To construct a figure showing on one side an angle of 30° and on the other an angle of 60°, by the use of

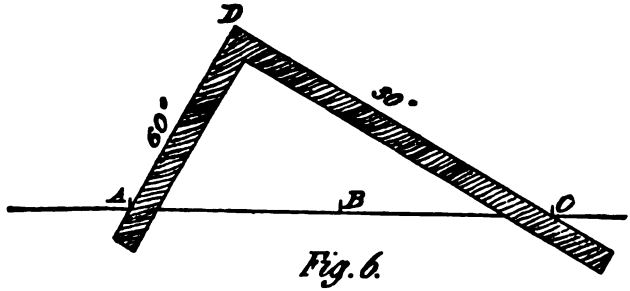


Fig. 6.

the steel square, we go to work as follows: Mark on the edge of a board two equal spaces as AB, BC, Fig. 6, apply the square, keeping its blade on AC and making

AD equal AB; then the angles 30° and 60° are formed as shown. If we make a templet cut exactly as shown in Fig. 5, also a templet cut as shown in this last figure, and these templets are made of some hard wood, we get a pair of set squares for drawing purposes, by which a large number of geometrical problems and drawing kinks may be wrought out.

The diameter of any circle within the range of the steel square may be determined by the instrument as follows: The corner of the square touching any part of the circumference A, Fig. 7, and the blade cutting in points C, B, gives the diameter of the circle as

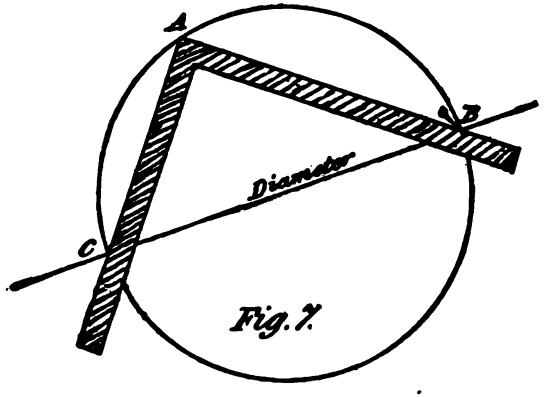


Fig. 7.

shown. Another application of this principle is, that the diameter of a circle being known, the square may be employed to describe the circumference. Suppose CB to be the known diameter; then put in two nails as shown, one at B and the other at C, apply the square, keeping its edges firmly against the nails, continually sliding it around, then the point of the square A will describe half the circumference. Apply the

square to the other side of the nails, and repeat the process, when the whole circle will be described. This problem may be applied to the solution of many others of a similar nature.

At Fig. 8, I show how an equilateral triangle may be obtained by the use of a square. Draw the line

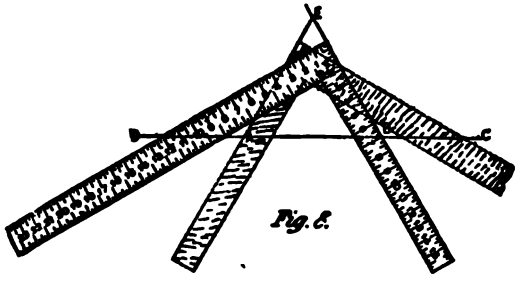


Fig. 8.

DC; take 12 on the blade and 7 on the tongue; mark on the tongue for one side of the figure. Make the distance from D to A equal to the desired length of one side of the figure. Reverse the square, placing it as shown by the dotted lines in the sketch, bringing 7 of the tongue against the point A. Scribe along the tongue, producing the line until it intersects the first line drawn in the point E, then AEB will be an equilateral triangle. A method of describing a hexagon by the square, is shown at Fig. 9, which is quite simple. Draw the line GH; lay off the required length of one side on this line, as DE. Place the square as before, with 12 of the blade and 7 of the tongue against the line GH; placing 7 of the tongue against the point D, scribe along the tongue for the side DC. Place the square as shown by the dotted lines; bringing 7 of the tongue against the point E, scribe the side EF. Con-

tinue in this way until the other half of the figure is drawn. All is shown by FABC.

The manner of bisecting angles has been shown in Figs. 2, 3 and 4 of the present chapter, so that it is not necessary to repeat the process at this time.

The method of describing an octagon by using the square, is shown at Fig. 10. Lay off a square

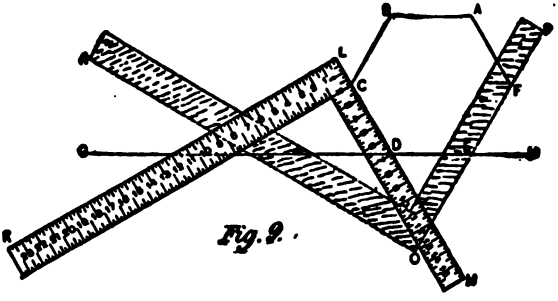


Fig. 9.

section with any length of sides, as AB. Bisect this side and place the square as shown on the side AB, with the length bisected on the blade and tongue; then the tongue cuts the side at the point to gauge for the piece to be removed. To find the size of square required for an octagonal prism, when the side is given: Let CD equal the given side; place the square on the

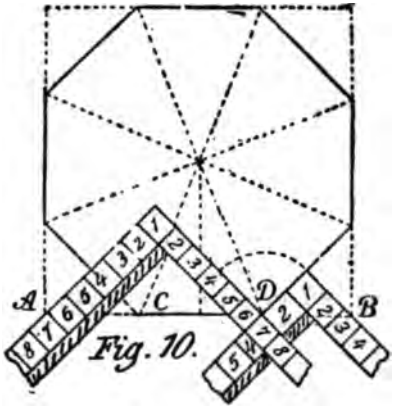


Fig. 10.

line of the side, with one-half of the side on the blade and tongue; then the tongue cuts the line at the point B, which determines the size of the square, and the piece to be removed.

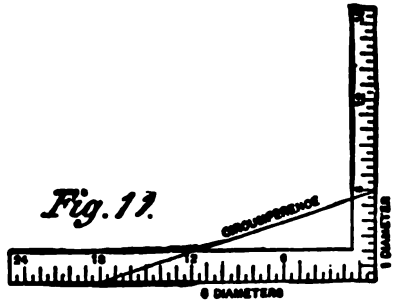


Fig. 11.

A near approximation to the length or stretch-out of a circumference of a circle may be obtained by the aid of the steel square and a straight line, as follows: Take three diameters of the circle and measure up the side of the blade of the square, as shown at Fig. 11, and fifteen-sixteenths of one diameter on the tongue. From these two points

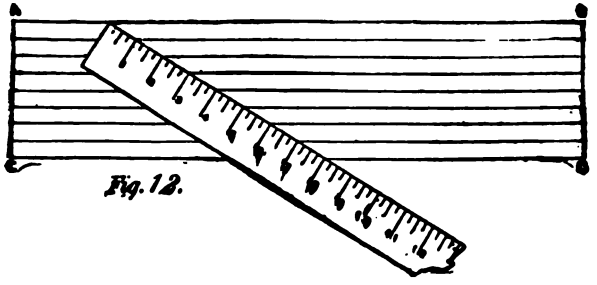


Fig. 12.

draw a diagonal, and the length of this diagonal will be the length or stretch-out of the circumference nearly.

If it is desired to divide a board or other substance into any given number of equal parts, without going through the process of calculation, it may readily be done by the aid of the square or even a pocket rule. Let AC, BD, Fig. 12, be the width of the board or

other material, and this width is seven and one-quarter inches, and we wish to divide it into eight equal parts. Lay on the board diagonally, with furthermost point of the square fair with one edge, and the mark 8 on the square on the other edge; then prick off the inches, 1, 2, 3, 4, 5, 6 and 7 as shown, and these points will be the gauge points from which to draw the parallel lines. These lines, of course, will be something less than one inch apart.

If the board should be more than eight inches wide, then a greater length of the square may be used, as for instance, if the board is ten inches wide, and we wish to divide it into eight equal parts, we simply make use of the figure 12 on the square instead of 8, and prick off the spaces every one and a half inches on the square. If the board is more than 12 inches wide, and we require the same number of divisions, we make use of figure 16 on the square, and prick off at every two inches. Any other divisions of the board may be obtained in a like manner, varying only the use of the figures on the square to get the number of divisions required.

As a number of problems in connection with actual work, will be wrought out on similar lines to the foregoing, further on in this book, I will close this chapter in order to give as much space as possible in describing the ellipse and the higher curves.

CHAPTER IV

ELLIPSES, SPIRALS, AND OTHER CURVES

The ellipse, next to the circle, is the curve the carpenter will be confronted with more than any other, and while it is not intended to discuss all, or even a major part, of the properties and characteristics of this curve, I will endeavor to lay before the reader all in connection with it that he may be called upon to deal with.

According to geometricians, an ellipse is a conic section formed by cutting a cone through the curved surface, neither parallel to the base nor making a subcontrary section, so that the ellipse like the circle is a curve that returns within itself, and completely encloses a space. One of the principal and useful properties of the ellipse is, that the rectangle under the two segments of a diameter is as the square of the ordinate. In the circle, the same ratio obtains, but the rectangle under the two segments of the diameter becomes equal to the square of the ordinate.

It is not necessary that we enter into a learned description of the relations of the ellipse to the cone and the cylinder, as the ordinary carpenter may never have any practical use of such knowledge, though, if he have time and inclination, such knowledge would avail him much and tend to broaden his ideas. Suffice for us to show the various methods by which this curve may be obtained, and a few of its applications to actual work.

One of the simplest and most correct methods of describing an ellipse, is by the aid of two pins, a string

and a lead-pencil, as shown at Fig. 1. Let FB be the major or longest axis, or diameter, and DC the minor or shorter axis or diameter, and E and K the two foci.

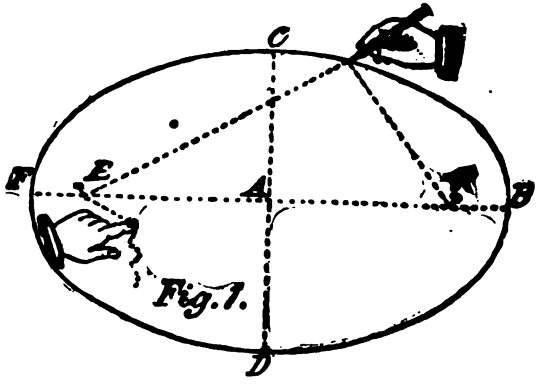


Fig. 1.

These two points are obtained by taking the half of the major axis AB or FA, on the compasses, and, standing one point at D, cut the points E and K on the line FB, and at these points insert the pins at E and K as shown. Take a string as shown by the dotted lines and tie to the pins at K, then stand the pencil at C and run the string round it and carry the string to the pin E, holding it tight and winding it once or twice around the pin, and then holding the string with the finger. Run the pencil around, keeping the loop of the string on the pencil and it will guide the latter in the formation of the curve as shown. When one-half of the ellipse is formed, the string may be used for the other half, commencing the curve at F or B, as the case may be. This is commonly called "a gardener's oval," because gardeners make use of it for forming ornamental beds for flowers, or in making curves for

walks, etc., etc. This method of forming the curve, is based on the well-known property of the ellipse that the sum of any two lines drawn from the focl to their circumference is the same.

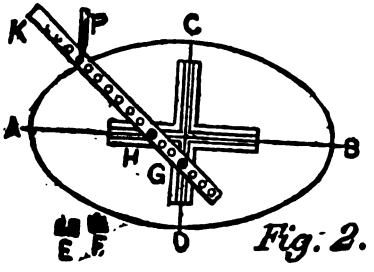


Fig. 2.

Another method of projecting an ellipse is shown at Fig. 2, by using a trammel. This is an instrument consisting of two principal parts, the fixed part in the form of a cross as CD, AB, and the movable tracer HG. The fixed piece is made of two triangular bars or pieces of wood of equal thickness, joined together so as to be in the same plane. On one side of the frame when made, is a groove forming a right-angled cross; the groove is shown in the section at E. In this groove, two studs are fitted to slide easily, the studs having a section same as shown at F. These studs are to carry the tracer and guide it on proper lines. The tracer may have a sliding stud on the end to carry a lead-pencil, or it may have a number of small holes passed through it as shown in the cut, to carry the pencil. To draw an ellipse with this instrument, we measure off half the distance of the major axis from the pencil to the stud G, and half the minor axis from the pencil point to the stud H, then swing the tracer round, and the pencil will describe the ellipse required. The studs have little projections on their tops, that fit easily into the holes in the tracer, but this may be done away with, and two brad awls or pins may be thrust through the tracer and into the studs, and then

proceed with the work. With this instrument an ellipse may easily be described.

Another method, based on the trammel principle, is shown at Figs. 3 and 4, where the steel square is substituted for the instrument shown in Fig. 2. Draw the line AB, bisecting it at right angles, draw CD. Set off these lines the required dimensions of the ellipse to be drawn. Place an ordinary square as shown. Lay the straightedge lengthwise of the figure, as shown in Fig. 3, and putting a pin at E against the square, place the pencil at F, at a point corresponding with the one of the figure. Next place the straightedge, as shown in Fig. 4, crosswise of the figure, and bring the pencil F to a point corresponding to one side of the figure, and set a pin at G. By keeping the two pins E and G against the square, and moving the straightedge so as to carry the pencil from side to side, one-quarter of the figure will be struck. By placing the square in the same relative position in each of the other three-quarters, the other parts may be struck.

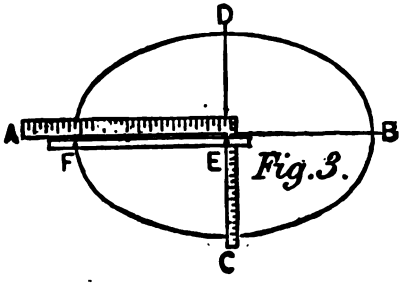


Fig. 3.

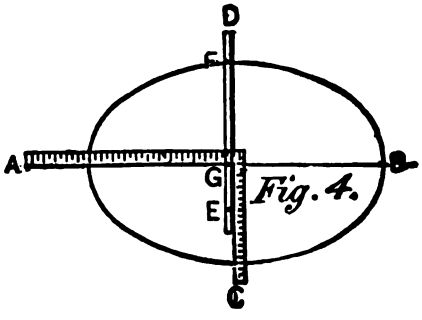


Fig. 4.

A method,—and one that is very useful for many purposes,—of drawing an ellipse approximately, is shown in Fig. 5. It is convenient and may be applied to hundreds of purposes, some of which will be illustrated as we proceed. To apply this method, work as follows: First lay off the length of the required figure, as shown by AB, Fig. 5, and the width as shown by CD. Construct a parallelogram that shall have its sides tangent to the figure at the points of its length and width, all as shown by EFGH. Subdivide one-half of the end of the parallelogram into any convenient number of equal parts, as shown at AE, and one-half of its side in the same manner, as shown by ED. Connect these two sets of points by intersecting lines in the manner shown in the engraving. Repeat the operation for each of the other corners of the parallelogram. A line traced through the inner set of intersections will be a very close approximation to an ellipse.

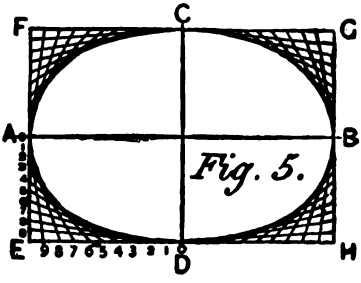


Fig. 5.

There are a number of ways of describing figures that approximate ellipses by using the compasses, some of them being a near approach to a true ellipse, and it is well that the workman should acquaint himself with the methods of their construction. It is only necessary that a few examples be given in this work, as a knowledge of these shown will lead the way to the construction of others when required. The method exhibited in Fig. 6 is, perhaps, the most useful of any employed by workmen, than all other methods com-

bined. To describe it, lay off the length CD, and at right angles to it and bisecting it lay off the width AB. On the larger diameter lay off a space equal to the shorter diameter or width, as shown by DE. Divide the remainder of the length or larger diameter EC into three equal parts; with two of these parts as a radius, and R as a center, strike the circle GSFT. Then, with F as a center and FG as radius, and G as center and GF as radius, strike the arcs as shown, intersecting each other and cutting the line drawn through the shorter diameter at O and P respectively From O, through the points G and F, draw OL and OM, and likewise from P through the same points draw PK and PN. With O as center and OA as radius, strike the arc LM, and with P as center and with like radius, or PB which is the same, strike the arc KN. With F and G as centers, and with FD and CG which are the same, for radii, strike the arcs NM and KL respectively, thus completing the figure. Another method in which the centers for the longer arc are outside the curve lines, is shown at Fig 7. Let AB be the length and CD the breadth; join BD through the center of the line EB, and at

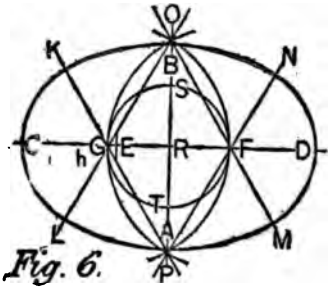


Fig. 6.

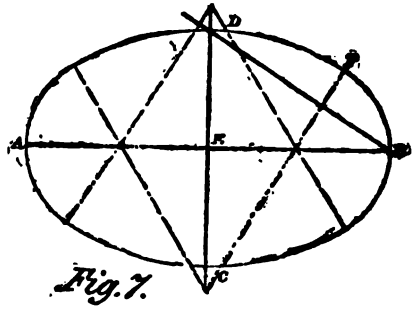


Fig. 7.

right angles to BD draw the line CF indefinitely; then at the points of intersection of the dotted lines will be found the points to describe the required ellipse. A method of describing an ellipse by the intersection of lines is shown at Fig. 8, and which may be applied to any kind of an ellipse with longer or shorter axis. Let WX be the given major axis, and YA the minor axis drawn at right angles to and at the center of each other.

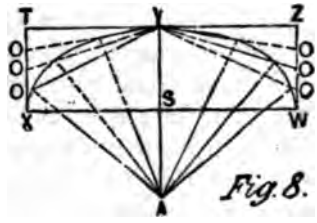


Fig. 8.

Through Y parallel to WX draw ZT, parallel to AY, draw WZ and XT; divide WZ and XT into any number of equal parts, say four, and draw lines from the points

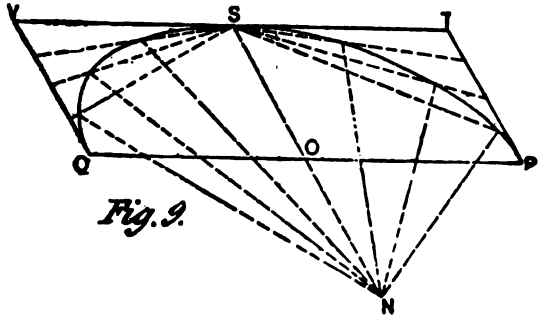


Fig. 9.

of division OOO, etc., to Y. Divide WS and XS each into the same number of equal parts as WZ and XT, and draw lines from A through these last points of division intersecting the lines drawn from OOO, etc., and at these intersections trace the semi-ellipse WYX. The other half of the ellipse may be described in the same manner.

To describe an ellipse from given diameters, by intersection of lines, even though the figure be on a rake: Let SN and QP, Fig. 9, be the given diameters, drawn through the centers of each other at any required angle. Draw QV and PT parallel to SN, through S draw TV parallel to QP. Divide into any number of equal parts PT, QV, PO, and OQ; then proceed as in Fig. 8, and the work is complete

An ellipse may be described by the intersection of arcs as at Fig. 10. Lay off HG and JK as the given axes; then find the foci as described in Fig. 1. Between L and L and the center M mark any number of points at pleasure as 1, 2, 3, 4. Upon L and L with H1 for radius describe arcs at O, O, O, O; upon L and with C1 for radius describe intersecting arcs at O, O, O, and

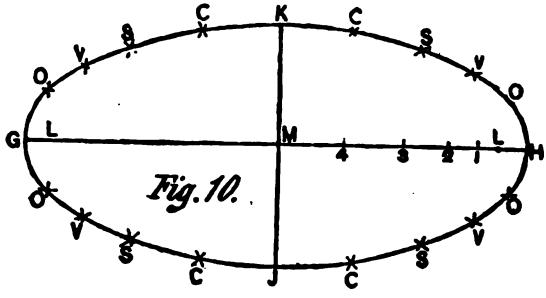
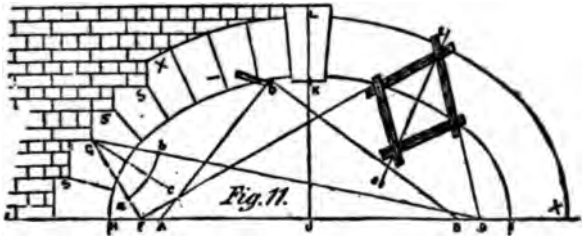


Fig. 10.

O; then these points of intersection will be in the curve of the ellipse. The other points V, S, C, are found in the same manner, as follows: For the point V take H2 for one radius, and G2 for the other; S is found by taking H3 for one radius, and G3 for the other; C is found in like manner, with H4 for one radius, and G4 for the last radius, using the foci for centers as at first. Trace a curve through the points H, O, V, S, C, K, etc., to complete the ellipse

It frequently happens that the carpenter has to make

the radial lines for the masons to get their arches in proper form, as well as making the centers for the same, and, as the obtaining of such lines for elliptical work is very tedious, I illustrate a device that may be employed that will obviate a great deal of labor in producing such lines. The instrument and the method of using it is exhibited at Fig. 11 and marked Ee. The semi-ellipse HI, or xx, may be described with a string or strings, the outer line being described by use of a string fastened to the foci F and D, with the extreme point at E; and the inner line, with the string being fastened at A and B, with the pencil point in the tightened string at O. The sectional line LKJ shows the center of the arch, and the lines SSS are at



right angles with this vertical line. The usual method of finding the normal by geometry is shown at GABC, but the more practical method of finding it is by the use of the instrument, where Ee shows the normal. I believe the device is of French origin, and I give a translation of a description and use of the instrument: "It is made of four pieces of lath or metal put together so as to form a perfect rectangle and having its joints loose, as shown in the diagram. Considering that the most perfect elliptical curve is that described by a string from the foci (foyer) of the ellipse, draw the profiles of the extrados and intrados, as shown in Fig. 11, where your joints are to be, then take your

string, draw it to the point marked as at E, adjust two sides of your instrument to correspond with the lines of the string, then, from the point marked, draw a line passing through the two angles, E and e, and the line Ee will be the normal or the radial line sought."

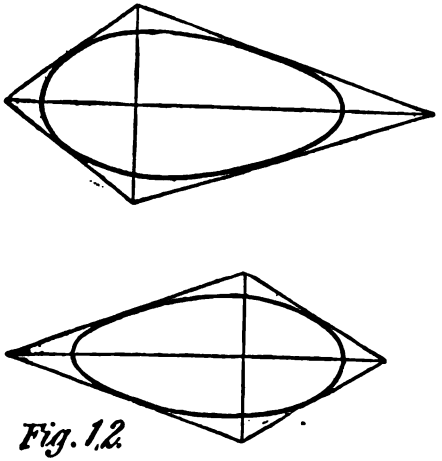


Fig. 12.

The oval is not an ellipse, nor are any of the figures obtained by using the compasses, as no part of an ellipse is a circle, though it may approach closely to it. The oval may sometimes be useful to the carpenter, and it may be well to illustrate one or two methods by which these figures may be described.

Let us describe a diamond or lozenge-shaped figure, such as shown at Fig. 12, and then trace a curve inside of it as shown, touching the four sides of the figure, and a beautiful egg-shaped curve will be formed. For effect we may elongate the lozenge or shorten it at will, placing the short diameter at any point. This form of oval is much used by turners and lathe men generally, in the formation of pillars, balusters, newel-posts and turned ornamental work generally.

An egg-shaped oval may also be inscribed in a figure having two unequal but parallel sides, both of which

are bisected by the same line, perpendicular to both as shown in Fig. 13. These few examples are quite sufficient to satisfy the requirements of the workman, as they give the key by which he may construct any oval he may ever be called upon to form.

I have dwelt rather lengthily on the subject of the ellipse because of its being rather difficult for the workman to deal with, and it is meet he should acquire a fair knowledge of the methods of constructing it. It is not my province to enter into all the details of the properties of this very intersecting figure, as the workman can find many of these in any good work on mensuration, if he should require more. I may say here, however, that geometricians so far have failed to discover any scientific method of forming parallel ellipses, so that while the inside or outside lines of an ellipse can be obtained by any of the methods I have given, the parallel line must be obtained either by gauging the width of the material or space required, or must be obtained by "pricking off" with compasses or other aid. I thought it best to mention this as many a young man has spent hours in trying to solve the unsolvable problem when using the pins, pencil and string.

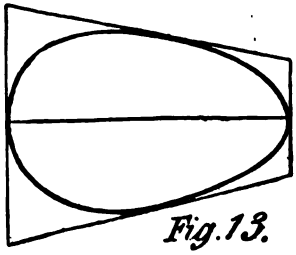


Fig. 13.

There are a number of other curves the carpenter will sometimes meet in daily work, chief among these being the scroll or spiral, so it will be well for him to have some little knowledge of its structure. A true spiral can be drawn by unwinding a piece of string that

has been wrapped around a cone, and this is probably the method adopted by the ancients in the formation of the beautiful Ionic spirals they produced. A spiral drawn by this method is shown at Fig. 14. This was formed by using two lead-pencils which had been sharpened by one of those patent sharpeners and which gave them the shape seen in Fig. 15. A piece of string was then tied tightly around the pencil, and one end was wound round the conical end, so as to lie in notches made in one of the pencils; the point of a second pencil was pierced through the string at a convenient point near the first pencil, completing the arrangement shown in Fig. 15. To draw the spiral the pencils must be kept vertical, the point of the first being held firmly in the hole of the spiral, and the second pencil must then be carried around the first, the distance between the two increasing regularly, of course, as the string unwinds.

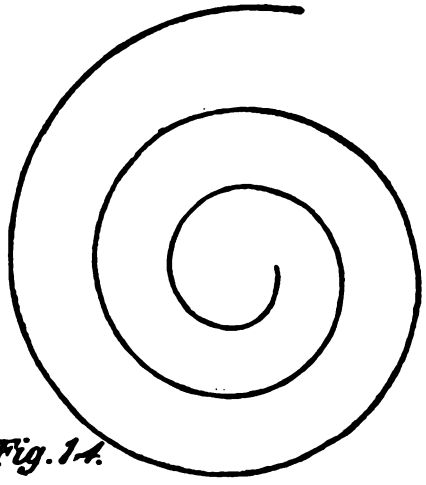


Fig. 14.

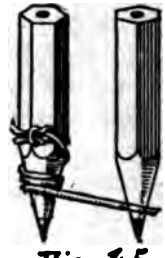


Fig. 15.

This is a rough-and-ready apparatus, but a true

spiral can be described by it in a very few minutes. By means of a larger cone, spirals of any size can, of course, be drawn, and that portion of the spiral can be used which conforms to the required height.

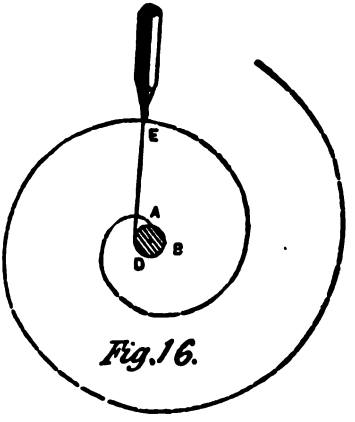


Fig. 16.

Another similar method is shown in Fig. 16, only in this case the string unwinds from a spool on a fixed center A, D, B. Make loop E in the end of the thread, in which place a pencil as shown. Hold the spool firmly and move the pencil around it, unwinding the thread. A curve will be described, as shown in the lines. It is evident that the proportions of the figure are determined by the size of the spool. Hence a larger or smaller spool is to be used, as circumstances require.

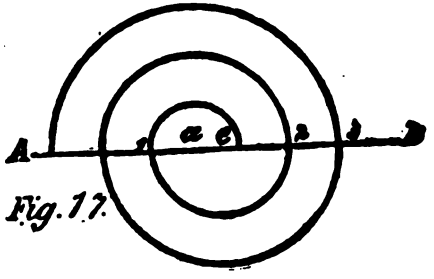


Fig. 17.

A simple method of forming a figure that corresponds to the spiral somewhat, is shown in Fig. 17. This is drawn from two centers only, a and e, and if the distance between these centers is not too great, a fairly smooth appearance will be given to the figure. The method

of describing is simple. Take a1 as radiu describe a semi-circle; then take e1 and d semi-circle 12 on the lower side of the line AB. with a2 as radius describe semi-circle above th again, with e3 as radius, describe semi-circle the line AB; lastly with a3 as radius describe circle above the line.

In the spiral shown at Fig. 18 we have one dr a scientific manner, and which can be form

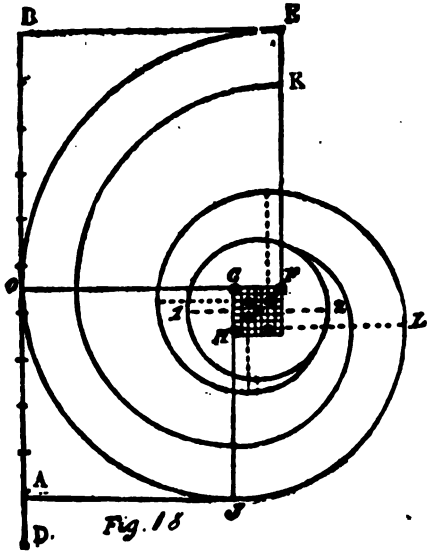


Fig. 18

dimensions. draw it, p as follows: BA be the breadth, ar number of tions, say o three-fourth multiply or three-fourt four, which seven; to add three number of t side of a sq contained diameter (eye, making all. Now divide AB into ten equal parts and from A to D, making eleven parts. Divide D two equal parts at O, then OB will be the radius first quarter OF, FE; make the side of the squ shown at GF, equal to one of the eleven par divide the number of parts obtained by multi the revolutions by four, which is seven; ma

diameter of the eye, 12, equal to three of the eleven parts. With F as a center and E as a radius make the quarter EO; then, with G as a center, and GO as a radius, mark the quarter OJ. Take the next center at H and HJL in the quarter; so keep on for centers, dropping one part each time as shown by the dotted angles. Let EK be any width desired, and carry it around on the same centers.

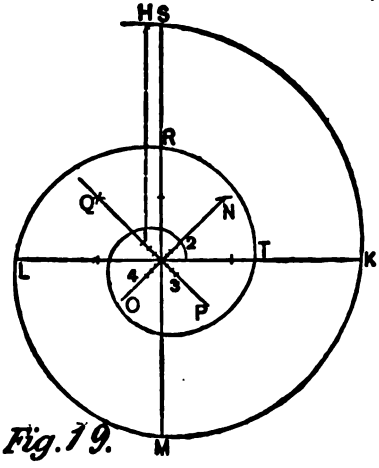


Fig. 19.

Another method of obtaining a spiral by arcs of circles is shown at Fig. 19, which may be confined to given dimensions. Proceed as follows: Draw SM and LK at right angles; at the intersection of these lines bisect the angles by the lines NO and QP; and on NO and QP from the intersection each way set off three equal parts as shown. On 1 as center and 1H as radius, describe the arc HK, on 2 describe the arc KM, on 3 describe the arc ML, on 4 describe the arc LR. The fifth center to describe the arc RT is under 1 on the line QP; and so proceed to complete the curve.

There are a few other curves that may occasionally prove useful to the workman, and I submit an example or two of each in order that, should occasion arise where such a curve or curves are required, they may be met with a certain amount of knowledge of the subject.

The first is the parabola, a curve sometimes used in bridge work or similar construction. Two examples of the curve are shown at Fig. 20, and the methods of describing them. The upper one is drawn as follows:

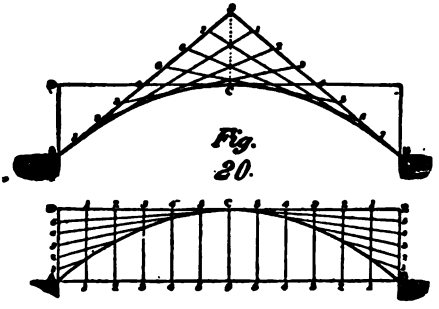


Fig. 20.

1. Draw C8 perpendicular to AB, and make it equal to AD.

Next, join A8 and B8, and divide both lines into the same number of equal parts, say 8; number them as in the figure; draw 1, 1-2, 2-3, 3, etc., then these lines will be tangents to the curve; trace the curve to touch the center of each of those lines between the points of intersection.

The lower example is described thus: 1. Divide AD and BE, into any number of equal parts; CD and CE into a similar number.

2. Draw 1, 1-2, 2, etc., parallel to AD, and from the points of division in AD and BE, draw lines to C. The points of intersection of the respective lines are points in the curve.

The curves found, as in these figures, are quicker at the crown than a true circular segment; but, where the rise of the arch is not more than one-tenth of the span, the variation cannot be perceived.

A raking example of this curve is shown in Fig. 21, and the method of describing it: Let AC be the ordinate or vertical line, and DB the axis, and B its vertex; produce the axis to E, and make BE equal to DB; join EC, EA, and divide them each into the same number

of equal parts, and number the divisions as shown on the figures. Join the corresponding divisions by the lines 11, 22, etc., and their intersections will produce the contour of the curve.

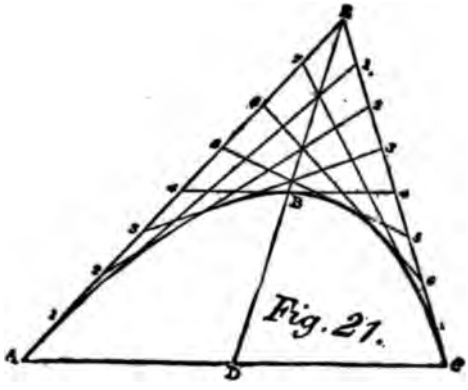


Fig. 21.

The hyperbola is somewhat similar in appearance to the parabola but it has properties peculiar to itself. It is a figure not much used in carpentry, but it may be well to refer to it briefly: Suppose there be two right equal cones, Fig. 22, having the same axis, and cut by a plane Mm, Nm, parallel to that axis, the sections MAN, mna, which result, are hyperbolas. In place of two cones opposite to each other, geometricians sometimes suppose four cones, which join on the lines EH, GB, Fig. 23, and of which axis form two right lines, Ff, F'f', crossing the center C in the same plane.

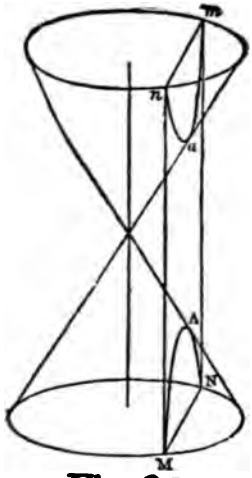


Fig. 22.

To describe a cycloid: The cycloid is the curve described by a point in the circumference of a circle rolling on a straight line, and is described as follows:

1. Let GH, Fig. 24, be the edge of a straight ruler, and C the center of the generating circle.

2. Through C draw the diameter AB perpendicular to GH, and EF parallel to GH; then AB is the height of the curve, and EF is the place of the center of the generating circle at every point of its progress.

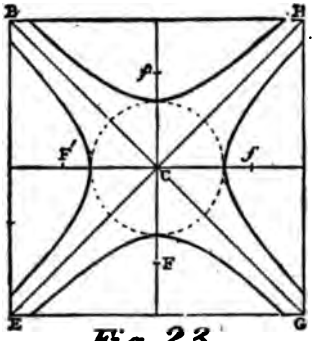


Fig. 23.

3. Divide the semi-circumference from B to A into any number of equal parts, say 8, and from A draw chords to the points of division.

4. From C, with a space in the dividers equal to one of the divisions on the circle, step off on each side the same number of spaces as the semi-circumference is divided into, and through the points draw perpendiculars to GH; number them as in the diagram.

5. From the points of division in EF with the

Fig. 24.

radius of the generating circle, describe indefinite arcs as shown by the dotted lines.

6. Take the chord A1 in the dividers, and with the foot at 1 and 1 on the line GH, cut the indefinite arcs

described from 1 and 1 respectively at D and D', then D and D' are points in the curve.

7. With the chord A2, from 2 and 2 in GH, cut the indefinite arcs in J and J', with the chord A3, from 3 and 3, cut the arcs in K and K' and apply the other chords in the same manner, cutting the arcs in LM, etc.

8. Through the points so found trace the curve.

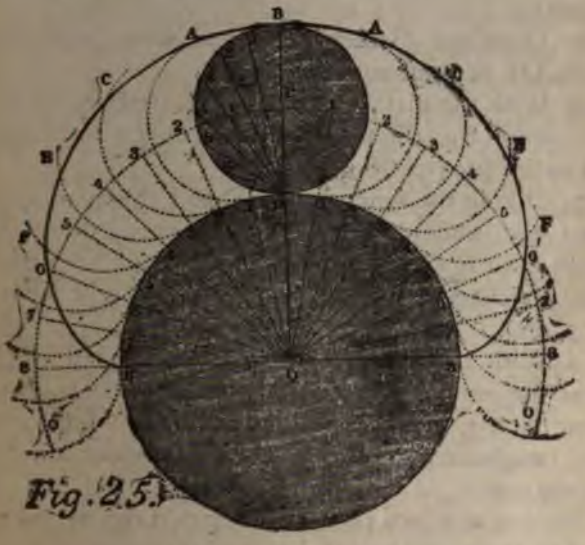


Fig. 25.

Each of the indefinite arcs in the diagram represents the circle at that point of its revolution, and the points D, J, K, etc., the position of the generating point B at each place. This curve is frequently used for the arches of bridges, its proportions are always constant, viz.: the span is equal to the circumference of the generating circle and the rise equal to the diameter. Cycloidal arches are frequently constructed which are

not true cycloids, but approach that curve in a greater or less degree.

The epicycloidal curve is formed by the revolution of a circle round a circle, either within or without its circumference, and described by a point B, Fig. 25, in the circumference of the revolving circle, and Q of the stationary circle.

The method of finding the points in the curve is here given:

1. Draw the diameter 8, 8 and from Q the center, draw QB at right angles to 8, 8.

2. With the distance QP from Q, describe an arc O, O representing the position of the center P throughout its entire progress.

3. Divide the semi-circle BD and the quadrants D8 into the same number of equal parts, draw chords from D to 1, 2, 3, etc., and from Q draw lines through the divisions in D8 to intersect the curve OO in 1, 2, 3, etc.

4. With the radius of P from 1, 2, 3, etc., in OO, describe indefinite arcs; apply the chords D1, D2, etc. from 1, 2, 3, etc., in the circumference of Q, cutting the indefinite arcs in A,C,E,F, etc., which are points in the curve.

We are now in a position to undertake actual work, and in the next chapter, I will endeavor to apply a part of what has preceded to practical examples, such as are required for every-day use. Enough geometry has been given to enable the workman, when he has mastered it all, to lay out any geometrical figure he may be called upon to execute; and with, perhaps, the exception of circular and elliptical stairs and hand-railings, which require a separate study, by what has been formulated and what will follow, he should be able to execute almost any work in a scientific manner, that may be placed under his control.

PART II

PRACTICAL EXAMPLES

CHAPTER I

We are now in a position to undertake the solution of practical examples, and I will commence this department by offering a few practical solutions that will bring into use some of the work already known to the student, if he has followed closely what has been presented.

It is a part of the carpenter's duty to lay out and construct all the wooden centers required by the bricklayer and mason for turning arches over openings of all kinds; therefore, it is essential he should know as much concerning arches as will enable him to attack the problems with intelligence. I have said something of arches, in Part I, but not sufficient to satisfy all the needs of the carpenter, so I supplement with the following on the same subject: Arches used in building are named according to their curves,—circular, elliptic, cycloid, parabolic, hyperbolic, etc. Arches are also known as three or four centered arches. Pointed arches are called lancet, equilateral and depressed. Voussoirs is the name given to the stones forming the arch; the central stone is called the keystone. The highest point in an arch is called the crown, the lowest the springing line, and the spaces between the crown and springing line on either side, the haunches or flanks. The under, or concave, sur-

face of an arch is called the intrados or soffit, the upper or convex surface is called the extrados. The span of an arch is the width of the opening. The supports of an arch are called abutments, piers, or

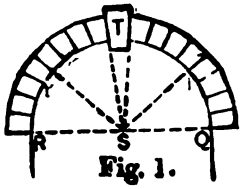


Fig. 1.

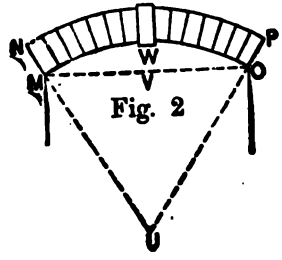


Fig. 2

springing walls. This applies to the centers of wood, as well as to brick, stone or cement. The following six illustrations show the manner of getting the curves, as well as obtaining the radiating lines, which, as a rule, the carpenter will be asked to prepare for the mason. We take them in the following order:

Fig. 1. A Semi-circular Arch.—RQ is the span, and the line RQ is the springing line; S is the center from

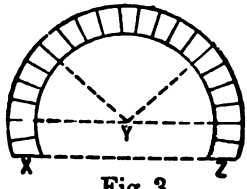


Fig. 3.

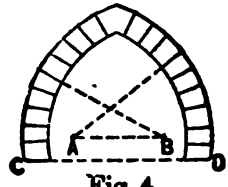


Fig. 4.

which the arch is described, and to which all joints of the voussoirs tend. T is the keystone of the arch.

Fig. 2. A Segment Arch.—U is the center from which the arch is described, and from U radiate all

the joints of the arch stones. The bed line of the arch OP or MN is called by mason builders a skew-back. OM is the span, and VW is the height or versed sine of the segment arch.

Figs. 3 and 4. Moorish or Saracenic Arches, one of which is pointed. Fig. 3 is sometimes called the horseshoe arch. The springing lines DC and ZX of both arches are below the centers BA and Y.

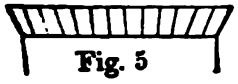


Fig. 5

Fig. 5. A Form of Lintol Called a Platband, built in this form as a substitute for a segment arch over the opening of doors or windows, generally of brick, wedge-shaped.

Fig. 6. The Elliptic Arch.—This arch is most perfect when described with the trammel, and in that case

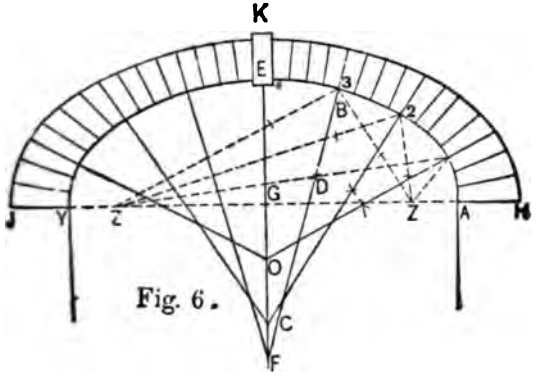


Fig. 6.

the joints of the arch stones are found as follows: Let ZZ be the foci, and B a point on the intrados where a joint is required; from ZZ draw lines to B, bisect the angle at B by a line drawn through the intersecting axis D produced for the joint to F. Joints at 1 and 2

are found in the same manner. The joints for the opposite side of the arch may be transferred as shown. The semi-axes of the ellipse, HG, GK, are in the same ratio as GE to GA. The voussoirs near the springing

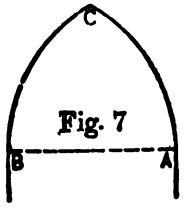


Fig. 7

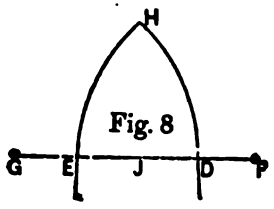


Fig. 8

line of the arch are thus increased in size for greater strength. I gave a very good description of this latter arch in Part I, which see.

Another series of arches, known as Gothic arches, are shown as follows, with all the centers of the curve given, so that their formation is rendered quite simple. The arch shown at Fig. 7 is equilateral and its outlines have been shown before. I repeat, however, let AB be the given span; on A and B as centers with AB as radius, describe the arcs AC and BC.

The lancet arch, Fig. 8, is drawn as follows: DE is the given span; bisect DE in J, make DF and EG equal DJ; on F as center with FE as radius describe

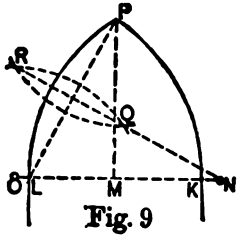


Fig. 9

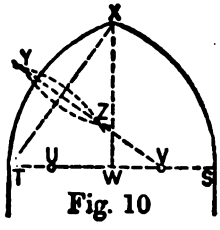


Fig. 10

the arc EH, and on G as center describe the arc DH.

A lancet arch, not so acute as the previous one, is

shown at Fig. 9. Let KL be the given span; bisect KL in M, make MP at right angles to KL and of the required height; connect LP, bisect LP by a line through the arcs R, Q produced to N; make MO equal MN; with N and O as centers, with NL for radius describe the arcs KP and LP. Fig. 10 shows a low or drop arch, and is obtained as follows: Let ST be the given span, bisect ST in W; let WX be the required height at right angles to TS; connect TX,

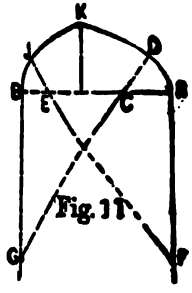


Fig. 11.

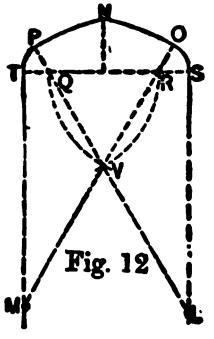


Fig. 12

bisect TX by a line through the arcs YZ produced to V, make TU equal SV; on V and U as centers with VT as radius describe the arcs TX and SX. Another Gothic arch with a still less height is shown at Fig. 11. Suppose AB to be the given span; then divide AB into four equal parts; make AF and BG equal AB, connect FE and produce to D; with CA as radius, on C and E, describe the arcs AD and BK; on F and G as centers, describe the arcs JK and DK.

Another four-centered arch of less height is shown at Fig. 12. Let SI be the given span, divide into six equal parts; on R and Q as centers with RQ as radius describe the arcs QV and RV, connect QV and RV and produce to L and M; on R and Q as centers with QT as

radius describe the arcs TP and SO; on L and M as centers describe the arcs PN and ON.

To describe an equilateral Ogee arch, like Fig. 13, proceed as follows: Make YZ the given span; make

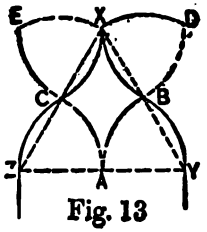


Fig. 13

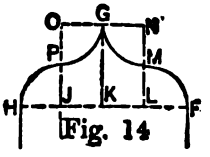


Fig. 14

YX equal YZ, bisect YZ in A; on A as center with AY as radius describe the arcs YB and ZC; on B and X as centers describe the arcs BD and XD, and on C and X as centers describe the arcs CE and XE, on E and D as centers describe the arcs BX and CX.

Fig. 14 shows the method of obtaining the lines for an Ogee arch, having its height equal to half the span. Suppose FH to be the span, divide into four equal parts, and at each of the points of division draw lines LN, KG and JO at right angles to FH; with LF for radius on L and J describe the quarter circles FM and HP; and with the same radius on O and N describe the quarter circles PG and MG.

These examples—all or any of them—can be made use of in a great number of instances. Half of the Ogee curve is often employed for veranda rafters, as for the roofs of bay-windows, for tower roofs and for bell bases, for oriel and bay-windows, and many other pieces of work the carpenter will be confronted with from time to time. They also have value as aids in forming mouldings and other ornamental work, as for

example Fig. 15, which shows a moulding for a base or other like purpose. It is described as follows: Draw AB; divide it into five equal parts; make CD equal to four of these. Through D draw DF parallel with AB. From D, with DC as radius, draw the arc CE. Make EF equal to DE; divide EF into five parts; make the line above F equal to one of these; draw FG equal to six of these. From G, with radius DE, describe the arc; bisect GF, and lay the distance to H. It is the center of the curve, meeting the semi-circle described from M. Join NO, OS, and the moulding is complete.

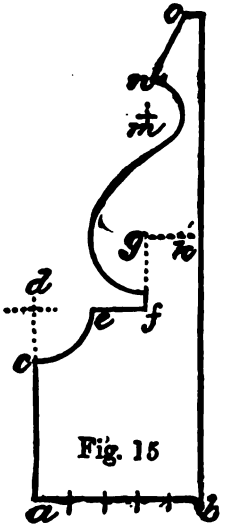


Fig. 15

The two illustrations shown at Figs. 16 and 17 will give the student an idea of the manner in which he can apply the knowledge he has now obtained, and it may not be out of place to say that with a little ingenuity he can form almost any sort of an ornament he wishes by using this knowledge. The two illustrations require no explanation as their formation is self-evident. Newel posts, balusters, pedestals and other turned or wrought ornaments, may be designed easily if a little thought be brought to bear on the subject.

The steel square is a great aid in working out problems in carpentry, and I will endeavor to show, as briefly as possible, how the square can be applied to some difficult problems, and insure correct solutions.

It is unnecessary to give a full and complete description of the steel square. Every carpenter and joiner is

supposed to be the possessor of one of these useful tools, and to have some knowledge of using it. It is not everyone, however, who thoroughly understands its powers or knows how to employ it in solving all

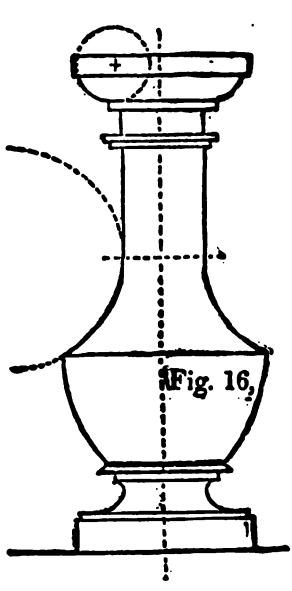


Fig. 16.

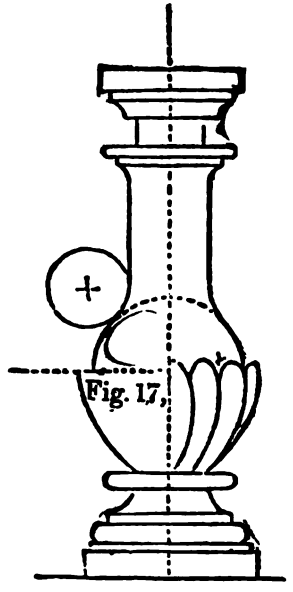


Fig. 17.

the difficulties of framing, or to take advantage of its capabilities in laying out work. While it is not my intention to go deeply into this subject in this volume, as that would lengthen it out to unreasonable limits, so it must be left for a separate work, yet there are some simple things connected with the steel square, that I think every carpenter and joiner should know, no matter whether he intends to go deeper into the study of the steel square or not. One of these things is the learning to read the tool. Strange as it may

appear, not over one in fifty of those who use the square are able to read it, or in other words, able to explain the meaning and uses of the figures stamped on its two sides. The following will assist the young fellows who want to master the subject.

The square consists of two arms, at right angles to each other, one of which is called the blade and which is two feet long, and generally two inches wide. The other arm is called the tongue, and may be any length from twelve to eighteen inches, and 1¼ to 2 inches in width. The best square has always a blade 2 inches wide. Squares made by firms of repute are generally perfect and require no adjusting or "squaring."

The lines and figures formed on squares of different make sometimes vary, both as to their position on the square and their mode of application, but a thorough understanding of the application of the scales and lines shown on any first-class tool, will enable the student to comprehend the use of the lines and figures exhibited on any good square.

It is supposed the reader understands the ordinary divisions and subdivisions of the foot and inch into twelfths, inches, halves, quarters, eighths and sixteenths, and that he also understands how to use that part of the square that is subdivided into twelfths of an inch. This being conceded, we now proceed to describe the various rules as shown on all good squares. Sometimes the inch is subdivided into thirty-seconds, in which the subdivision is very fine, but this scale will be found very convenient in the measurement of drawings which are made to a scale of half, quarter, one-eighth or one-sixteenth of an inch to a foot.

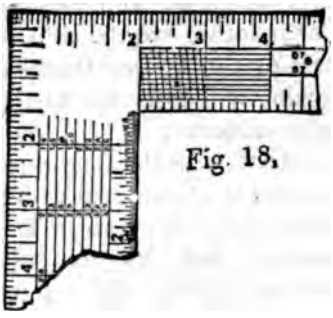


Fig. 18.

In the illustration Fig. 18, will be noticed a series of lines extending from the junction of the blade and tongue to the four-inch limit. From the figures 2 to 3 these lines are crossed by diagonal lines. This figure, reaching from 2 to 4, is called a diagonal scale, and is intended for taking off hundredths of an inch The

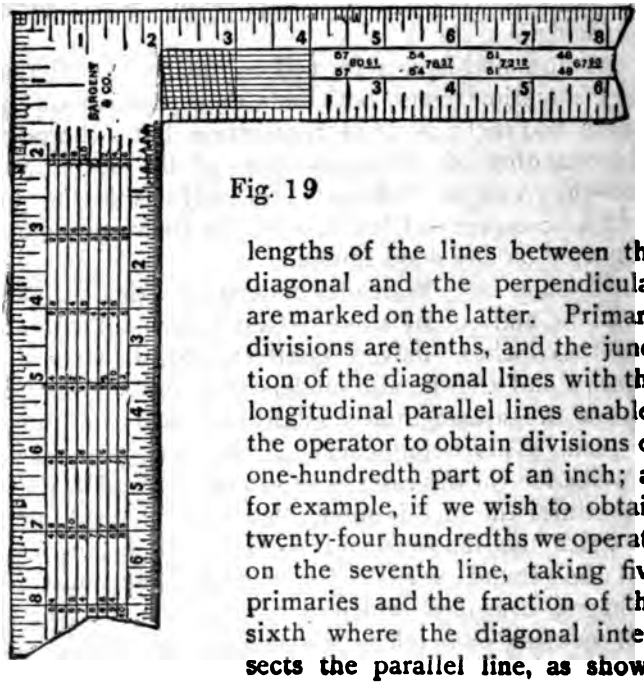


Fig. 19

lengths of the lines between the diagonal and the perpendicular are marked on the latter. Primary divisions are tenths, and the junction of the diagonal lines with the longitudinal parallel lines enables the operator to obtain divisions of one-hundredth part of an inch; as for example, if we wish to obtain twenty-four hundredths we operate on the seventh line, taking five primaries and the fraction of the sixth where the diagonal intersects the parallel line, as shown

by the "dots" on the compasses, and this gives us the distance required.

The use of the scale is obvious, and needs no furtner explanation, as the dots or points are shown.

The lines of figures running across the blade of the square, as shown in Fig. 19, forms what is a very convenient rule for determining the amount of material in length or width of stuff. To use it proceed as follows: If we examine we will find under the figure 12, on the outer edge of the blade, where the length of the boards, plank or scantling to be measured is given, and the answer in feet and inches is found under the inches in width that the board, etc., measures. For example, take a board nine feet long and five inches wide, then under the figure 12, on the second line, will be found the figure 9, which is the length of the board; then run along this line to the figure directly under the five inches (the width of the board) and we find three feet nine inches, which is the correct answer in 'board measure." If the stuff is three inches thick it is trebled, etc., etc. If the stuff is longer than any figures shown on the square it can be measured as above and doubling the result. This rule is calculated, as its name indicates, for board measure, or for surfaces 1 inch in thickness. It may be advantageously used, however, upon timber by multiplying the result of the face measure of one side of a piece by its depth in inches. To illustrate, suppose it be required to measure a piece 25 feet long, 10x14 inches in size. For the length we will take 12 and 13 feet. For the width we will take 10 inches, and multiply the result by 14. By the rule a board 12 feet long and 10 inches wide contains 10 feet, and one 13 feet long and 10 inches wide, 10 feet 10 inches. Therefore, a board 25 feet long and 10 inches wide must contain 20 feet and

10 inches. In the timber above described, however, we have what is equivalent to 14 such boards, and therefore we multiply this result by 14, which gives 291 feet and 8 inches the board measure.

Along the tongue of the square following the diagonal scale is the brace rule, which is a very simple and very convenient method of determining the length of any brace of regular run. The length of any brace simply represents the hypothenuse of a right-angled triangle. To find the hypothenuse extract the square root of the sum of the squares of the perpendicular and horizontal runs. For instance, if 6 feet is the horizontal run and 8 feet the perpendicular, 6 squared equals 36, 8 squared equals 64; 36 plus 64 equals 100, the square root of which is 10. These are the rules generally used for squaring the frame of a building.

If the run is 42 inches, 42 squared is 1764, double that amount, both sides being equal, gives 3528, the square root of which is, in feet and inches, 4 feet 11.40 inches.

In cutting braces always allow in length from a sixteenth to an eighth of an inch more than the exact measurement calls for.

Directly under the half-inch marks on the outer edge of the back of the tongue, Fig. 19, will be noticed two figures, one above the other. These represent the run of the brace, or the length of two sides of a right-angled triangle; the figures immediately to the right represent the length of the brace or the hypothenuse. For instance, the figures $\frac{5}{8}\frac{7}{1}$, and 80.61 show that the run on the post and beam is 57 inches, and the length of the brace is 80.61 inches.

Upon some squares will be found brace measurements given, where the run is not equal, as $\frac{12}{12}$.30. It will be noticed that the last set of figures are each just

three times those mentioned in the set that are usually used in squaring a building. So if the student or mechanic will fix in his mind the measurements of a few runs, with the length of braces, he can readily work almost any length required.

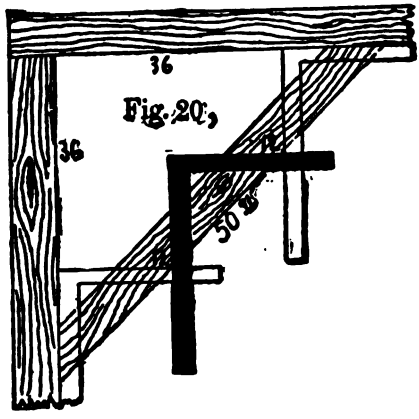


Fig. 20.

Take a run, for instance, of 9 inches on the beam and 12 inches on the post. The length of brace is 15 inches. In a run, therefore, of 12, 16, 20, or any number of times above the figures, the length of the brace will bear the same proportion to the run as the multiple used. Thus if you multiply all the figures by 3 you will have 36 and 48 inches for the run, and 60 inches for the brace, or to remember still more easily, 3, 4 and 5 feet.

There is still another and an easier method of obtaining the lengths of braces by aid of the square, also the bevels as may be seen in Fig. 20, where the run is 3 feet, or 36 inches, as marked. The length and bevels of the brace are found by applying the square three times in the position as shown; placing 12 and 12 on the edge of the timber each time. By this method both length and bevel are obtained with the least amount of labor. Braces having irregular runs may be oberated in the same manner. For instance, suppose we wish to set in a brace where the run is 4 feet and 3 feet; we simply take 9 inches on the

tongue and 12 inches on the blade and apply the square four times, as shown in Fig. 21, where the brace is given in position. Here we get both the proper length and the exact bevels. It is evident from this that braces, regular or irregular, and of any length, may be obtained with bevels for same by this method, only care must be taken in adopting the figures for the purpose.

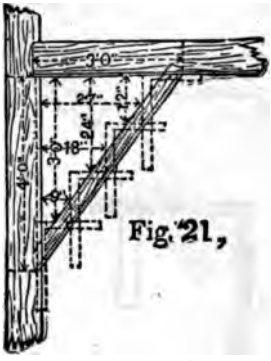


Fig. 21,

If we want a brace with a two-foot run and a four-foot run, it must be evident that as two is the half of four, so on the square take 12 inches on the tongue, and 6 inches on the blade, apply four times and we have the length and the bevels of a brace for this run.

For a three-by-four foot run take 12 inches on the tongue and 9 inches on the blade, and apply four times, because as 3 feet is ¾ of four feet, so 9 inches is ¾ of 12 inches.

While on the subject of braces I submit the following table for determining the length of braces for any run from six inches to fourteen feet. This table has been carefully prepared and may be depended upon as giving correct measurements. Where the runs are regular or equal the bevel will always be a miter or angle of 45°, providing always the angle which the brace is to occupy is a right angle—a "square." If the run is not equal, or the angle not a right angle, then the bevels or "cuts" will not be miters, and will have to be obtained either by taking figures on the square or by a scaled diagram.

TABLE

Length of Run			Length of Brace		Length of Run			Length of Brace	
ft.	in.		ft.	in.	ft.	in.		ft.	in.
6		6 =		8.48	4 3		4 3 =	6	0.12
6		9 =		10.81	4 3		4 6 =	6	2.27
9		9 =	1	0.72	4 3		4 9 =	6	4.49
10		10 =	1	4.97	4 3		5 0 =	6	6.74
10		13 =	1	7.20	4 6		4 6 =	6	4.36
13		13 =	1	9.23	4 6		4 9 =	6	6.51
13		16 =	1	11.43	4 6		5 0 =	6	8.72
16		16 =	2	1.45	4 9		4 9 =	6	8.61
16		19 =	2	3.65	4 9		5 0 =	6	10.75
19		19 =	2	5.69	5 0		5 0 =	7	0.85
19		20 =	2	7.89	5 3		5 3 =	7	5.09
20		20 =	2	9.94	5 6		5 6 =	7	9.33
20		23 =	3	0.12	5 9		5 9 =	8	1.58
20		26 =	3	2.41	6 0		6 0 =	8	5.82
23		26 =	3	4.36	6 3		6 3 =	8	10.06
26		26 =	3	6.42	6 6		6 6 =	9	2.30
26		29 =	3	8.59	6 9		6 9 =	9	6.55
29		29 =	3	10.66	7 0		7 0 =	9	10.79
29		30 =	4	0.83	7 3		7 3 =	10	3.03
30		30 =	4	2.91	7 6		7 6 =	10	7.28
30		33 =	4	5.02	7 9		7 9 =	10	11.52
30		36 =	4	7.31	8 0		8 0 =	11	3.76
30		39 =	4	9.62	8 3		8 3 =	11	8.00
33		33 =	4	7.15	8 6		8 6 =	12	0.24
33		36 =	4	9.31	8 9		8 9 =	12	4.49
33		39 =	4	11.54	9 0		9 0 =	12	8.73
33		40 =	5	1.84	9 6		9 6 =	13	5.22
36		36 =	4	11.39	10 0		10 0 =	14	1.70
36		39 =	5	1.55	10 6		10 6 =	14	10.19
36		40 =	5	3.78	11 0		11 0 =	15	6.67
39		39 =	5	3.63	11 6		11 6 =	16	3.16
39		40 =	5	5.79	12 0		12 0 =	16	11.64
40		40 =	5	7.88	12 6		12 6 =	17	8.13
40		43 =	5	10.03	13 0		13 0 =	18	4.61
40		46 =	6	0.25	13 6		13 6 =	19	1.10
40		49 =	6	2.51	14 0		14 0 =	19	9.58
40		50 =	6	4.83					

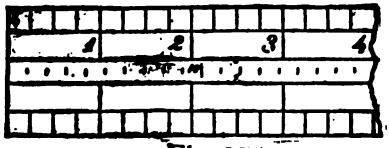


Fig. 22.

There is on the tongue of the square a scale called the "octagonal scale." This is generally on the opposite side to the scales shown on Fig. 19. Fig. 22 exhibits a portion of the tongue on which this scale is shown. It is the central division on which the number 10 is seen along with a number of divisions. It is used in this way: If you have a stick 10 inches square which you wish to dress up octagonal, make a center mark on each face, then with the compasses, take 10 of the spaces marked by the short cross-lines in the middle of the scale, and lay off this distance each side of the center lines, do the same at the other end of the stick, and strike a chalk line through these marks. Dress off the corners to the lines, and the stick will be octagonal. If the stick is not straight it must be gauged, and not marked with the chalk line. Always take a number of spaces equal to the square width of the octagon in inches. This scale can be used for large octagons by doubling or trebling the measurements.

Fig. 23.

On some squares, there are other scales, but I do not advise the use of squares that are surcharged with too many scales and figures, as they lead to confusion and loss of time.

It will now be in order to offer a few things that can be done with the steel square, in a shorter time than by applying any other methods. If we wish to get the

length and bevels for any common rafter it can be done on short notice by using the square as shown in Fig. 23. The pitch of the roof will, of course, govern the figures to be employed on the blade and tongue. For a quarter pitch, the figures must be 6 and 12. For half pitch, 12 and 12 must be used. For a steeper pitch, 12 and a larger figure must be used according to the pitch required. For the lower pitches, 8 and 12 gives a one-third pitch and 9 and 12 a still steeper pitch; and from this the workman can obtain any pitch he requires. If the span is 24 feet, the square must be applied 12 times, as 12 is half of 24. And so with any other span: The square must be applied half as many times as there are feet in the width. This is self-evident. The bevels and lengths of hip and valley rafters may be obtained in a similar manner, by first taking the length of the diagonal line between 12 and 12, on the square, which is 17 inches in round numbers. Use this figure on the blade, and the "rise" whatever that may be, on the tongue. Suppose we have a roof of one-third pitch, which has a span of 24 feet; then 8, which is one-third of 24, will be the height of the roof at the point or ridge, from the base of the roof on a line with the plates. For example, always use 8, which is one-third of 24, on tongue for altitude; 12, half the width of 24, on blade for base. This cuts common rafter. Next is the hip rafter. It must be understood that the diagonal of 12 and 12 is 17 in framing, as before stated, and the hip is the diagonal of a square added to the rise of roof; therefore we take 8 on tongue and 17 on blade; run the same number of times as common rafter. To cut jack rafters, divide the number of openings for common rafter. Suppose we have 5 jacks, with six open-

ings, our common rafter 12 feet long, each jack would be 2 feet shorter, first 10 feet, second 8 feet, third 6 feet, and so on. The top down cut the same as cut of common rafter; foot also the same. To cut miter to fit hip: Take half the width of building on tongue and length of common rafter on blade; blade gives cut. Now find the diagonal of 8 and 12, which is $14\frac{7}{16}$, take 12 on tongue, $14\frac{7}{16}$ on blade; blade gives cut. The hip rafter must be beveled to suit; height of hip on tongue, length of hip on blade; tongue gives bevel. Then we take 8 on tongue, 8¾ on blade; tongue gives the bevel. Those figures will span all cuts in putting on cornice or sheathing. To cut bed moulds for gable to fit under cornice, take half width of building on tongue, length of common rafter on blade; blade gives cut; machine mouldings will not member, but this gives a solid joint; and to member properly it is necessary to make moulding by hand, the diagonal plumb cut differences. To cut planceer to run up valley, take height of rafter on tongue, length of rafter on blade; tongue gives cut. The plumb cut takes the height of hip rafter on tongue, length of hip rafter on blade; tongue gives cut. These figures give the cuts for one-third pitch only, regardless of width of building. The construction of roofs generally will be taken up in another chapter.

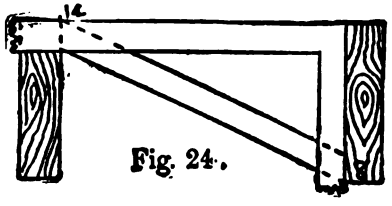


Fig. 24.

A ready way of finding the length and cuts for cross-bridging is shown at Fig. 24. If the joists are 8 inches wide and 16 inches centers, there will be 14 inches

between. Place the square on 8 and 14, and cut on 8, and you have it. The only point to observe is that the 8 is on the lower side of the piece of bridging, while the 14 is on the upper, and not both on same side of timber, as in nearly all work. Bridging for any depth of joists, to any reasonable distance of joists apart, may be obtained by this method. A quick way of finding the joists for laying out timber to be worked from the square to an octagon section is shown at Fig. 25. Lay your square diagonally across your timber and mark at 7 and 17, which gives corner of octagon. The figures 7 and 17, on either a square or two-foot pocket rule, when laid on a board or piece of timber as shown, always define the points where the octagonal angle or arris should be.

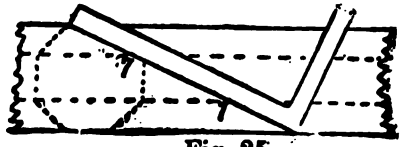


Fig. 25.

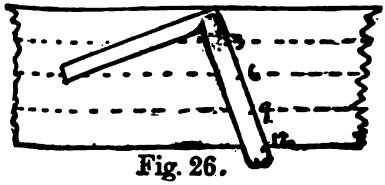


Fig. 26.

Fig. 26 shows a rapid method of dividing anything into several equal parts. If the board is 10½ inches wide, lay the square from heel to 12, and mark at 3, 6 and 9, and you have it divided into four equal parts. Any width of board or any number of parts may be worked with accuracy under the same method.

A method for obtaining the "cuts" for octagon and hexagon joints is shown at Fig. 27. Lay off a quarter circle XA, with C as a center; then along the horizontal line AB the square is laid with 12″ on the blade

at the center C, from which the quadrant was struck. If we divide this quadrant into halves, we get the point E, and a line drawn from 12″ on the blade of the square and through the point E, we cut the tongue of the square at 12″ and through to O, and the line thus drawn makes an angle of 45°, a true miter. If we divide the quadrant between E and X, and then draw a line from C, and 12″ on the blade of the square, cutting the dividing point D, we get the octagon cut, which is the line DC. Again, if we divide the space

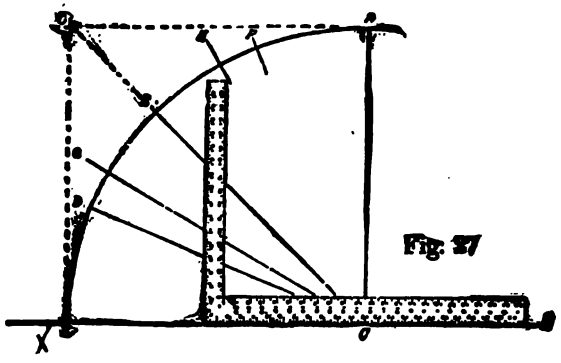


Fig. 27

between E and X into three equal parts, making GC one of these parts, and draw a line from C to G cutting the tongue of the square at 7″, we get a cut that will give us a miter for a hexagon; therefore, we see from this that if we set a steel square on any straight edge or straight line, 12″ and 12″ on blade and tongue on the line or edge, we get a true miter by marking along the edge of the blade. For an octagon miter, we set the blade on the line at 12″, and the tongue at 5″, and we get the angle on the line of the blade—nearly; and, for a hexagon cut, we place the blade at 12″ on the

line, and the tongue at 7", and the line of the blade gives the angle of cut—nearly. The actual figure for octagon is $4\frac{3}{8}$, but 5" is close enough; and for a hexagon cut, the exact figures are 12" and $6\frac{1}{8}$, but 12" and 7" is as near as most workmen will require, unless the cut is a very long one.

The diagram shown at Fig. 28 illustrates a method of defining the pitches of roofs, and also gives the figures on the square for laying out the rafters for such pitches. By a very common usage among carpenters and builders, the pitch of a roof is described by indicating what fraction the rise is of the span. If, for example, the span is 24 feet (and here it should be remarked that the diagram shows only one-half the span), then 6 feet rise would be called quarter pitch, because 6 is one-quarter of 24. The rule, somewhat arbitrarily expressed, that is applicable

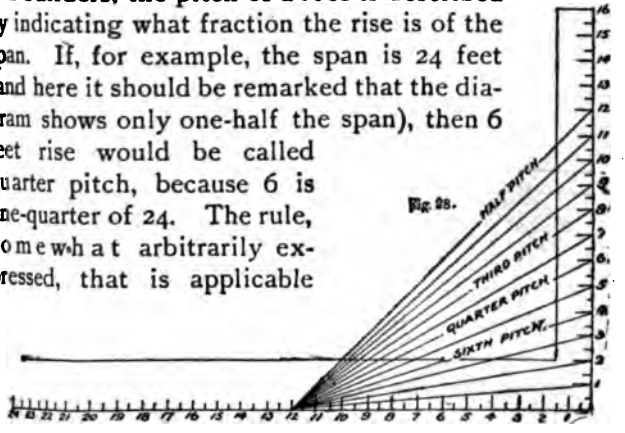


Fig. 28.

in such cases in roof framing where the roof is one-quarter pitch, is as follows: Use 12 of the blade, and 6 of the tongue. For other pitches use the figures appropriate thereto in the same general manner.

The diagram indicates the figures for sixth pitch, quarter pitch, third pitch and half pitch. The first three of these are in very common use, although the latter is somewhat exceptional.

It will take but a moment's reflection upon the part

of a practical man, with this diagram before him, to perceive that no changes are necessary in the rule where the span is more or less than 24 feet. The cuts are the same for quarter pitch irrespective of the actual dimensions of the building. The square in all such cases is used on the basis of similar triangles. The broad rule is simply this: To construct with the square such a triangle as will proportionately and correctly represent the full size, the blade becomes the base, the tongue the altitude or rise, while the hypothenuse that results represents the rafter. The necessary cuts are shown by the tongue and blade respectively.

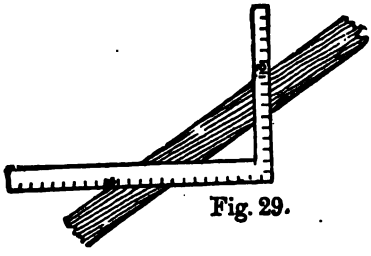


Fig. 29.

In order to give a general idea of the use of the square I herewith append a few illustrations of its application in framing a roof of, say, one-third pitch, which will be supposed to consist of common rafters, hips, valleys, jack rafters and ridges. Let it be assumed that the building to be dealt with measures 30 feet from outside to outside of wall plates; the toe of the rafters to be fair with the outside of the wall plates, the pitch being one-third (that is the roof rises from the top of the wall plate to the top of the ridge, one-third of the width of the building, or 10 feet), the half width of the building being 15 feet. Thus, the figures for working on the square are obtained; if other figures are used, they must bear the same relative proportion to each other.

To get the required lengths of the stuff, measure across the corner of the square, from the 10-inch mark

on the tongue to the 15-inch mark on the blade, Fig. 29. This gives 18 feet as the length of the common rafter. To get the bottom bevel or cut to fit on the wall plate, lay the square flat on the side of the rafter. Start, say, at the right-hand end, with the blade of the square to the right, the point or angle of the square away from you, and the rafter, with its back (or what will be the top edge of it when it is fixed) towards you. Now place the 15-inch mark of the blade and the 10-inch mark of the tongue on the corner of the rafter—that is, towards you—still keeping the square laid flat, and mark along the side of the blade. This gives the bottom cut, and will fit the wall plate. Now move the square to the other end of the rafter, place it in the same position as before to the 18-foot mark on the rafter and to the 10-inch mark on the tongue, and the 15-inch mark on the blade; then mark alongside the tongue. This gives the top cut to fit against the ridge. To get the length of the hip rafter, take 15 inches on the blade and 15 inches on the tongue of the square, and measure across the corner. This gives $21\frac{3}{16}$ inches. Now take this figure on the blade and 10 inches on the tongue, then measuring across the corner gives the length of the hip rafter.

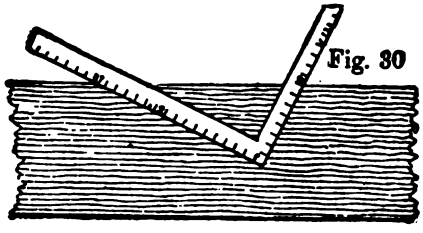


Fig. 30

Another method is to take the 17-inch mark on the blade and the 8-inch mark on the tongue and begin as with the common rafter, as at Fig. 30. Mark along

the side of the blade for the bottom cut. Move the square to the left as many times as there are feet in the half of the width of the building (in the present case, as we have seen, 15 feet is half the width), keeping the above mentioned figures 17 and 8 in line with the top edge of the hip rafter; step it along just the same as when applying a pitch board on a stair-string, and after moving it along 15 steps, mark alongside the tongue. This gives the top cut or bevel and the length. The reason 17 and 8 are taken on the square is that 12 and 8 represent the rise and run of the common rafter to 1 foot on plan, while 17 and 8 correspond with the plan of the hips.

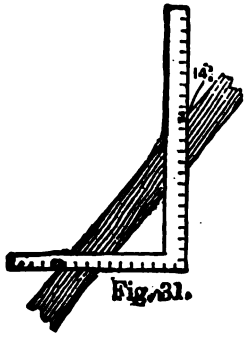


Fig. 31.

To get the length of the jack rafters, proceed in the same manner as for common or hip rafters; or alternately space the jacks and divide the length of the common rafter into the same number of spaces. This gives the length of each jack rafter.

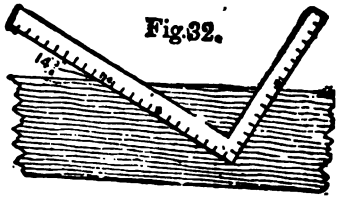


Fig. 32.

To get the bevel of the top edge of the jack rafter, Fig. 31, take the length, 14⅜ of the common rafter on the blade and the run of the common rafter on the tongue, apply the square to the jack rafter, and mark along the side of the blade; this gives the bevel or cut. The down bevel and the bevel at the bottom end are the same as for the common rafter

To get the bevel for the side of the purlin to fit

against the hip rafter, place the square flat against the side of the purlin, with 8 inches on the tongue and 14⅜ inches on the blade, Fig. 32. Mark alongside of the tongue. This gives the side cut or bevel. The 14⅜ inches is the length of the common rafter to the 1-foot run, and the 8 inches represent the rise.

For the edge bevel of purlin, lay the square flat against the edge of purlin with 12 inches on the tongue and 14⅜ inches on the blade, as at Fig. 33, and mark along the side of the tongue. This gives the bevel or cut for the edge of the purlin.

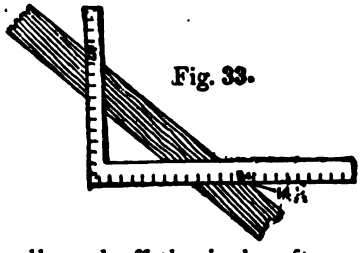


Fig. 33.

The rafter patterns must be cut half the thickness of ridge shorter; and half the thickness of the hip rafter allowed off the jack rafters.

These examples of what may be achieved by the aid of the square are only a few of the hundreds that can be solved by an intelligent use of that wonderful instrument, but it is impossible in a work of this kind to illustrate more than are here presented. The subject will be dealt with at length in a separate volume.

CHAPTER II

GENERAL FRAMING AND ROOFING

Heavy framing is now almost a dead science in this country unless it be in the far west or south, as steel and iron have displaced the heavy timber structures that thirty or forty years ago were so plentiful in roofs, bridges and trestle-work. As it will not be

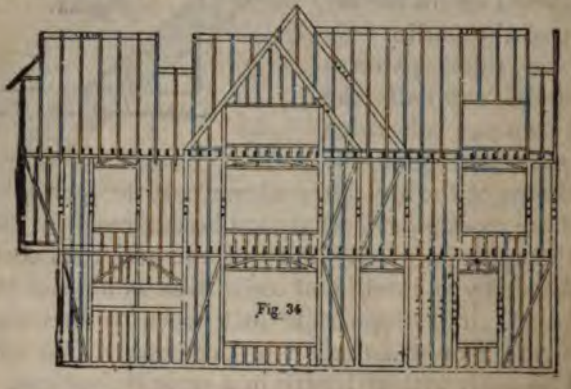


Fig. 34

necessary to go deeply into heavy-timber framing, therefore I will confine myself more particularly to the framing of ballon buildings generally.

A ballon frame consists chiefly of a frame-work of scantling. The scantling may be 2 x 4 inches, or any other size that may be determined. The scantlings are spiked to the sills, or are nailed to the sides of the joist which rests on the sills, or, as is sometimes the case, a rough floor may be nailed on the joists,

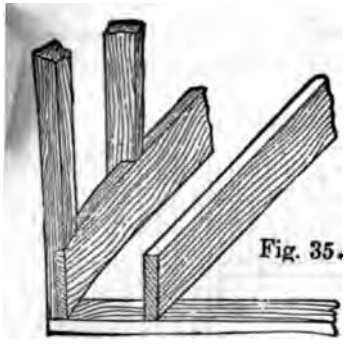


Fig. 35.

and on this, ribbon pieces of 2 x 4-inch stuff are spiked around to the outer edge of the foundation, and onto these ribbon pieces the scantling is placed and "toe-nailed" to them. The doors and windows are spaced off as shown in Fig. 34, which represents a ballon frame and roof in skeleton condition. These frames are generally boarded on both sides, always on the outside. Sometimes the boarding on the outside is nailed on diagonally, but more frequently horizontally, which, in my opinion, is the better way, providing always the boarding is dry and the joints laid close.

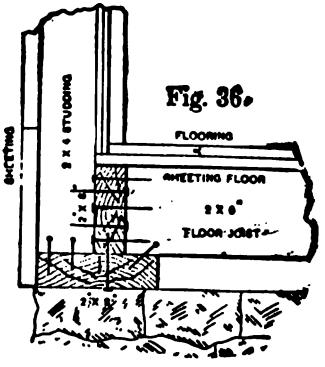


Fig. 36.

The joists are laid on "rolling," that is, there are no gains or tenons employed, unless in trimmers or similar work. The joists are simply "toe-nailed" onto sill plates, or ribbon pieces, as shown in the illustration. Sometimes the joists are made to rest on the sills, as shown in Fig. 35, the sill being no more than a 2 x 4-inch scantling laid in mortar on the foundation, the outside joists forming a sill for the side studs. A better plan is

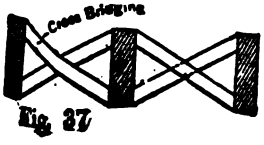


Fig. 37

shown in Fig. 36, which gives a method known as a "box-sill." The manner of construction is very simple.

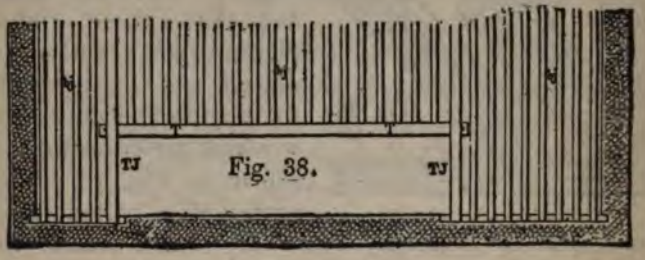


Fig. 38.

All joists in a building of this kind must be bridged similar to the manner shown in Fig. 37, about every eight feet of their length; in spans less than sixteen feet, and more than eight feet, a row of bridging should always be put in midway in the span. Bridging should not be less than 1 to 1½ inches in section.

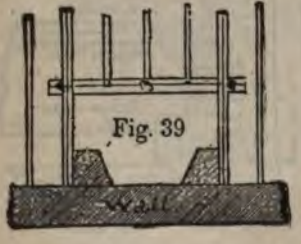


Fig. 39

In trimming around a chimney or a stair well-hole, several methods are employed. Sometimes the headers and trimmers are made from material twice as thick and the same depth as the ordinary joists, and the intermediate joists are tenoned into the header, as shown in Fig. 38. Here we have T, T, for header, and T, J, T, J, for trimmers, and *b*, *j*, for the ordinary joists. In the western, and also some of the central States, the trimmers and headers are made up of two thicknesses, the header being mortised to secure the ends of the joists. The

two thicknesses are well nailed together. This method is exhibited at Fig. 39., which also shows one way to trim around a hearth; C shows the header with trimmer joists with tusk tenons, keyed solid in place.

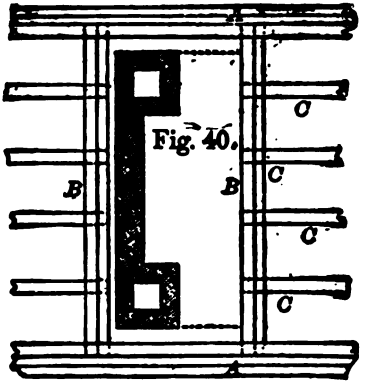


Fig. 40.

Frequently it happens that a chimney rises in a building from its own foundation, disconnected from the walls, in which case the chimney shaft will require to be trimmed all around, as shown in

Fig. 41.

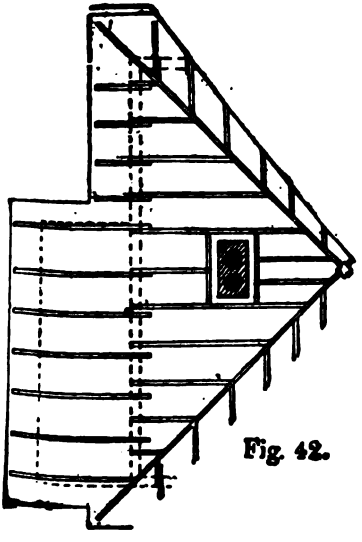


Fig. 42.

Fig. 40. In cases of this kind the trimmers A, A, should be made of stuff very much thicker than the joists, as they have to bear a double burden; B, B shows the heading, and C, C, C, C the tail joists. B, B, should have a thickness double that of C, C, etc., and A, A should at least be

three times as stout as C, C. This will to some exte equalize the strength of the whole floor, which is matter to be considered in laying down floor timber for a floor is no stronger than its weakest part.

There are a number of devices for trimming arour stairs, fire-places and chimney-stacks by which tl cutting or mortising of the timbers is avoided. Or method is to cut the timbers the exact length, squa in the ends, and then inse iron dowels—two or more- in the ends of the joist and then bore holes in th trimmers and headers to sui and drive the whole soli together. The dowels ai made from ¾-inch or 1-inc round iron. Another and better device is the "brid iron," which may be hooke over the trimmer or heade as the case may be, the sti rup carrying the abutting timber, as shown in Fig. 4 These "bridle irons" are made of wrought iron- 2 x 2½ inches, or larger dimensions if the work require such; for ordinary jobs, however, the size given wi be found plenty heavy for carrying the tail joists, and little heavier may be employed to carry the heade This style of connecting the trimmings does not hol the frame-work together, and in places where there i any tendency to thrust the work apart, some provisio must be made to prevent the work from spreading.

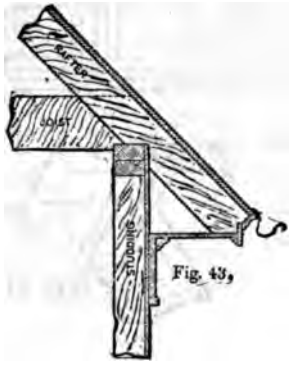


Fig. 43.

In trimming for a chimney in a roof, the "headers," "stretchers" or "trimmers," and "tail rafters," ma be simply nailed in place, as there is no great weigh

beyond snow and wind pressure to carry, therefore the same precautions for strength are not necessary. The sketch shown at Fig. 42 explains how the chimney openings in the roof may be trimmed, the parts being only spiked together. A shows a hip rafter against which the cripples on both sides are spiked. The chimney-stack is shown in the center of the roof—isolated—trimmed on the four sides. The sketch is

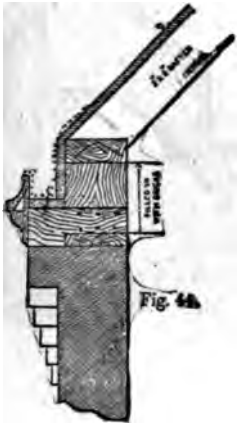


Fig. 44.

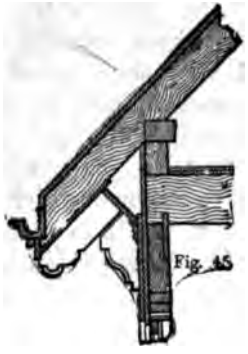


Fig. 45.

self-explanatory in a measure, and should be easily understood.

An example or two showing how the rafters may be connected with the plates at the eaves and finished for cornice and gutters, may not be out of place. A simple method is shown at Fig. 43, where the cornice is complete and consists of a few members only. The gutter is attached to the crown moulding, as shown.

Another method is shown at Fig. 44, this one being intended for a brick wall having sailing courses over cornice. The gutter is built in of wood, and is

lined throughout with galvanized iron This makes a substantial job and may be used to good purpose on brick or stone warehouses, factories or similar buildings.

Another style of rafter finish is shown at Fig. 45, which also shows scheme of cornice. A similar finish is shown at Fig. 46, the cornice being a little different. In both these examples, the gutters are of wood, which should be lined with sheet metal of some sort in order to prevent their too rapid decay. At Fig. 47 a rafter finish is shown which is intended for a veranda or porch. Here the construction is very simple. The rafters are dressed and cut on projecting end to represent brackets and form a finish

Fig. 46.

From these examples the workman will get sufficient ideas for working his rafters to suit almost any condition. Though there are many hundreds of styles which might be presented, the foregoing are ample for our purpose.

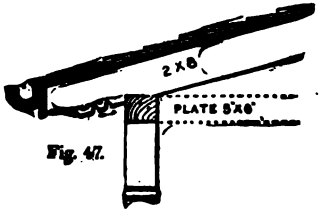


Fig. 47.

It will now be in order to take up the construction of roofs, and describe the methods by which such construction is obtained.

The method of obtaining the lengths and bevels of

rafters for ordinary roofs, such as that shown in Fig 48, has already been given in the chapter on the steel square. Something has also been said regarding hip and valley roofs; but not enough, I think, to satisfy the full requirements of the workman, so I will endeavor to give a clearer idea of the construction of these roofs by employing the graphic system, instead of depending altogether on the steel square, though I

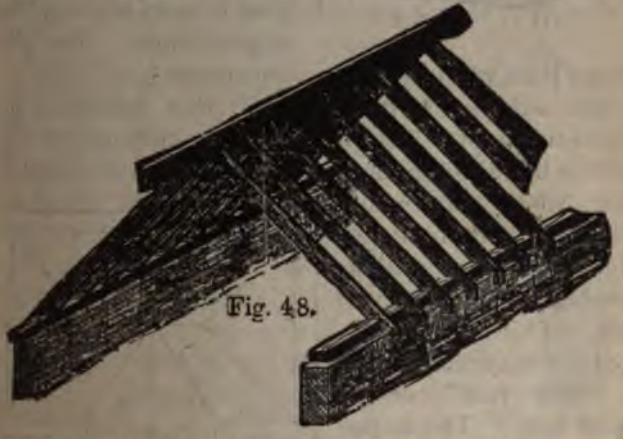


Fig. 48.

earnestly advise the workman to "stick to the square." It never makes a mistake, though the owner may in its application.

A "hip roof," pure and simple, has no gables, and is often called a "cottage roof," because of its being best adapted for cottages having only one, or one and a half, stories. The chief difficulty in its construction is getting the lengths and bevels of the hip or angle rafter and the jack or cripple rafter. To the expert workman, this is an easy matter, as he can readily obtain both lengths and bevels by aid of the square, or by lines such as I am about to produce.

The illustration shown at Fig. 49 shows the simplest form of a hip roof. Here the four hips or diagonal rafters meet in the center of the plan. Another style of hip roof, having a gable and a ridge in the center of the building, is shown at Fig. 50. This is quite a common style of roof, and under almost every condition it looks well and has a good effect. The plan shows lines of hips, valleys and ridges.

Fig. 49.

The simplest form of roof is that known as the "lean-to" roof. This is formed by causing one side wall to be raised higher than the opposite side wall, so that when rafters or joists are laid from the high to the low wall a sloping roof is the result. This style of a roof is sometimes called a "shed roof" or a "pent roof." The shape is shown at Fig. 51, the upper sketch showing an end view and the lower one a plan of the roof. The method of framing this roof, or adjusting the timbers for it, is quite obvious and needs no explanation. This style of roof is in general use where an annex or shed is built up against a superior building, hence its name of "lean-to," as it usually "leans" against the main building, the wall of which is utilized for the

Fig. 50

high part of the shed or annex, thus saving the cost of the most important wall of the structure.

Next to the "lean-to" or "shed roof" in simplicity comes the "saddle" or "double roof." This roof is shown at Fig. 52 by the end view on the top of the figure, and the plan at the bottom. It will be seen that this roof has a double slope, the planes forming the slopes are equally inclined to the horizon; the meeting of their highest sides makes an arris which is called the ridge of the roof; and the triangular spaces at the end of the walls are called gables.

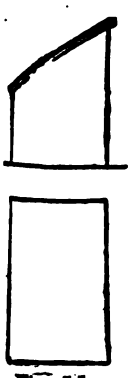


Fig. 51.

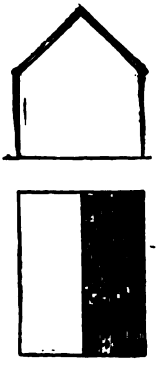


Fig. 52.

It is but a few years ago when the mansard roof was very popular, and many of them can be found in the older parts of the country, having been erected between the early fifties and the eighties, but, for many reasons, they are now less used. Fig. 53 shows a roof of this kind. It is penetrated generally by dormers, as shown in the sketch, and the top is covered either by a "deck roof" or a very flat hip roof, as shown. Sometimes the sloping sides of these roofs are curved, which give them a graceful appearance, but adds materially to their cost.

Another style of roof is shown at Fig. 54. This is a gambrel roof, and was very much in evidence in pre-revolutionary times, particularly among our Knickerbocker ancestors. In conjunction with appropriate dormers, this style of roof figures prominently in what is known as early "colonial style." It has some

advantages over the mansard. Besides these there are many other kinds of roofs, but it is not my purpose to enter largely into the matter of styles of roofs, but simply to arm the workman with such rules and practical equipment that he will be able to tackle with success almost any kind of a roof that he may be called upon to construct.

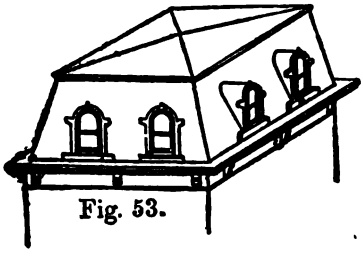


Fig. 53.

When dealing with the steel square I explained how the lengths and bevels for common rafters could be obtained by the use of the steel square alone; also hips, purlins, valleys and jack rafters might be obtained by the use of the square, but, in order to fully equip the workman, I deem it necessary to present for his benefit a graphic method of obtaining the lengths, cuts and backing of rafters and purlins required for a hip roof.

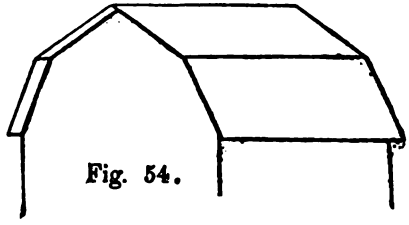


Fig. 54.

At Fig. 55, I show the plans of a simple hip roof having a ridge. The hips on the plan form an angle of 45°, or a miter, as it were. The plan being rectangular leaves the ridge the length of the difference between the length and the width of the building. Make *cd* on the ridge-line as shown, half the width of *ab*, and the angle *bda* will be a right angle. Then if we extend *bd* to *e*, making *de* the rise of the roof, *ae* will be the length of the hip rafter, and the

angle at *x* will be the plumb cut at point of hip and the angle at *a* will be the cut at the foot of the rafter. The angle at *v* shows the backing of the hip. This bevel is obtained as follows: Make *ag* and *ah* equal distances—any distance will serve—then draw a line *hg* across the angle of the building, then with a center on *ad* at *p*, touching the line *ac* at *s*, describe a circle as shown by the dotted line, then draw the lines *kh* and

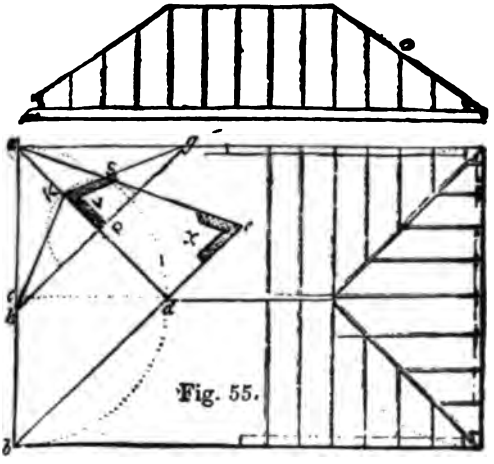
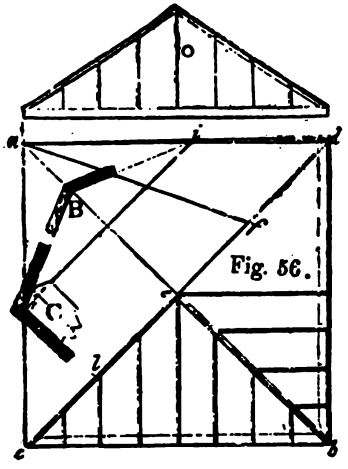


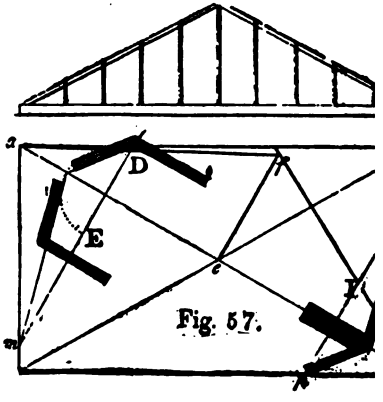
Fig. 55.

kg, and that angle, as shown by the bevel *v*, will be the backing or bevel for the top of the hip, beveling each way from a center line of the hip. This rule for backing a hip holds good in all kinds of hips, also for guttering a valley rafter, if the bevel is reversed. A hip roof where all the hips abut each other in the center is shown in Fig. 56. This style of roof is generally called a "pyramidal roof," because it has the appearance of a low flattened pyramid. The same rules governing Fig. 55 apply to this example. The bevels C and B show the backing of the hip, B showing the



top from the center *ae*; and C showing bevel as placed ag the side of the hip, v is always the better to work the hip. A tion of the hip back shown at C. The ri the roof is shown at

At Fig. 57 a plan roof is shown wher seats of the hips ar on an angle of 45° where the ends and of the roof are of diff pitches Take the base line of the hip, *ae* or *eg* make *ef* perpendicular to *ae*, from *e*, and equ the rise at *f*; make *fa* or *fg* for the length of the by drawing the line *lm* at right angles to *ae*. gives the length of the hip rafter. The backing c hip is obtained in a like manner to former exam only, in cases of this kind, there are two bevels for the backing, one side of the hip being more acute than the other as shown at D and E. If the hips are to be mitered, as is sometimes the case in roofs of this kind, then



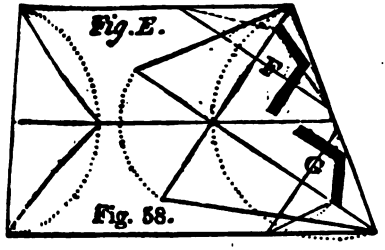


Fig. 58.

the back of the hip will assume the shape as shown by the two bevels at F. A hip roof having an irregular plan is shown at Fig. 58. This requires no explanation, as the hips and bevels are obtained in the same manner as in previous examples. The backing of the hips is shown at FG.

An octagon roof is shown at Fig. 59, with all the lines necessary for getting the lengths, bevels, and backing for the hips. The line *ax* shows the seat of the hip, *xe* the rise of roof, and *ae* the length of hip and plumb cut, and the bevel at E shows the backing of the hips.

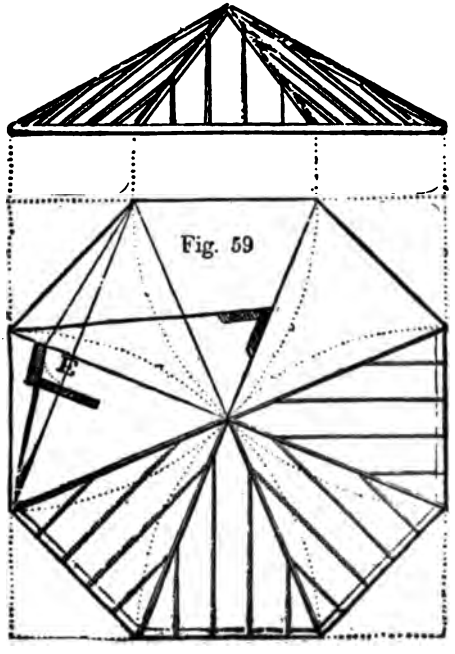


Fig. 59

These examples will be quite sufficient to enable the workman to understand the general theory of laying out hip roofs. I

may also state that to save a repetition of drawing and explaining the rules that govern the construction of hip roofs, such as I have presented serve equally well for skylights or similar work. Indeed, the clever workman will find hundreds of instances in his work where the rules given will prove useful.

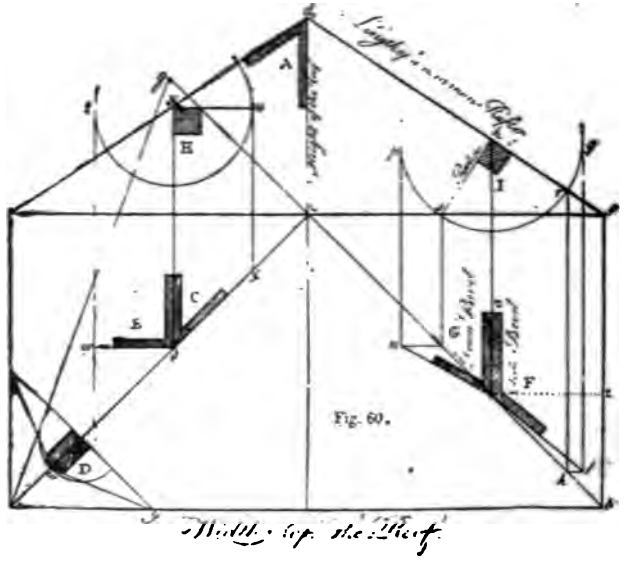


Fig. 60.

There are a number of methods for getting the lengths and bevels for purlins. I give one here which I think is equal to any other, and perhaps as simple. Suppose Fig. 60 shows one end of a hip roof, also the rise and length of common rafters. Let the purlin be in any place on the rafter, as I, and in its most common position, that is, standing square with the rafter; then with the point *b* as a center with any radius, describe a circle. Draw two lines, *ql* and *pn*, to touch

the circle *p* and *q* parallel to *fb* and at the points *s* and *r*, where the two sides of the purlin intersect, draw two parallel lines to the former, to cut the diagonal in *m* and *k*; then G is the down bevel and F the side bevel of the purlin; these two bevels, when applied to the end of the purlin, and when cut by them, will exactly fit the side of the hip rafters.

To find the cuts of a purlin where two sides are parallel to horizon: The square at B and the bevel at C will show how to draw the end of the purlin in this easy case. The following is universal in all positions of the purlin: Let *ab* be the width of a square roof, make *bf* or *ae* one-half of the width, and make *cd* perpendicular in the middle of *ef*, the height of the roof or rise, which in this case is one-third; then draw *de* and *df*, which are each the length of the common rafter.

To find the bevel of a jack rafter against the hip, proceed as follows: Turn the stock of the side bevel at F from *a* around to the line *iz*, which will give the side bevel of the jack rafter The bevel at A, which is the top of the common rafter, is the down bevel of the jack rafter.

At D the method of getting the backing of a hip rafter is shown the same as explained in other figures.

There are other methods of obtaining bevels for purlins, but the one offered here will suffice for all practical purposes.

I gave a method of finding the back cuts for jack rafters by the steel square, in a previous chapter. I give another rule herewith for the steel square: Take the length of the common rafter on the blade and the run of the same rafter on the tongue, and the blade of the square will give the bevel for the cut on the back

of the jack rafter. For example, suppose the
be 6 feet and the run 8 feet, the length of the
rafter will be 10 feet. Then take 10 feet on t
of the square, and 8 feet on the tongue, and t
will give the back bevel for the cut of t
rafters.

To obtain the length of jack rafters is a very
process, and may be obtained easily by a dia
shown in Fig. 61, which is a very common

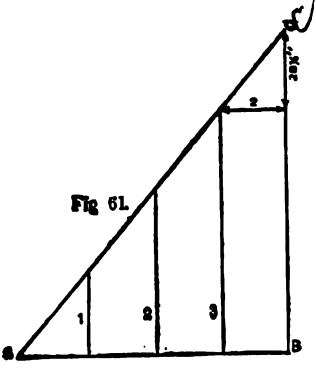


Fig 61.

First lay off half t
of the building to
from A to B, the le
the common rafter
and the length of
rafter from A to C.
off the widths fr
rafter to jack rafter
by the lines 1, 2,
measure them acc
Then the lines 1,
will be the exact le
the jack rafters in those divisions Any nu
jack rafters may be laid off this way, and th
will be the length of each rafter, no matter w
be the pitch of the roof or the distance the ra
apart.

A table for determining the length of jack r
given below, which shows the lengths requ
different spacing in three pitches:

One-quarter pitch roof:

They cut 13 5 inches shorter each time whe
12 inches.

They cut 18 inches shorter each time when
16 inches.

They cut 27 inches shorter each time when spaced 24 inches.

One-third pitch roof:

They cut 14.4 inches shorter each time when spaced 12 inches.

They cut 19.2 inches shorter each time when spaced 16 inches.

They cut 28.8 inches shorter each time when spaced 24 inches.

One-half pitch roof:

They cut 17 inches shorter each time when spaced 12 inches.

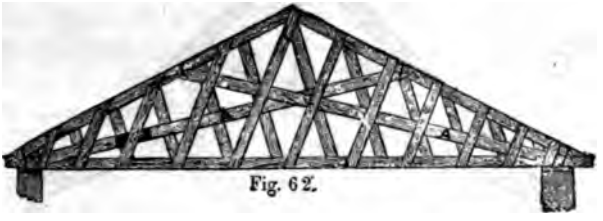


Fig. 62.

They cut 22.6 inches shorter each time when spaced 16 inches.

They cut 34 inches shorter each time when spaced 24 inches.

It is not my intention to enter deeply into a discussion of the proper methods of constructing roofs of all shapes, though a few hints and diagrams of octagonal, domical and other roofs and spires will doubtless be of service to the general workman. One of the most useful methods of trussing a roof is that known as a lattice "built-up" truss roof, similar to that shown at Fig. 62. The rafters, tie beams and the two main braces A, A, must be of one thickness—say, 2 x 4 or 2 x 6 inches, according to the length of the span—while the minor braces are made of 1-inch stuff and

about 10 or 12 inches wide. These minor braces are well nailed to the tie beams, main braces and rafters. The main braces must be halved over each other at their juncture, and bolted. Sometimes the main braces are left only half the thickness of the rafters, then no halving will be necessary, but this method has the disadvantage of having the minor braces nailed to one side only. To obviate this, blocks may be nailed to the inside of the main braces to make up the thickness

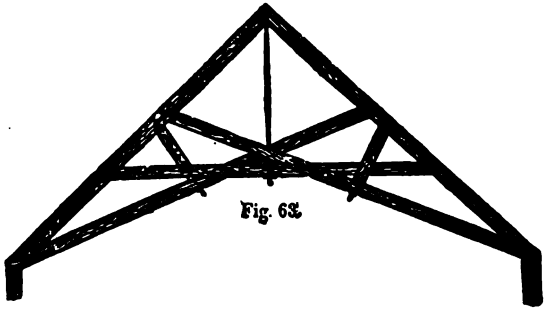


Fig. 63.

required, as shown, and the minor braces can be nailed or bolted to the main brace.

The rafters and tie beams are held together at the foot of the rafter by an iron bolt, the rafter having a crow-foot joint at the bottom, which is let into the tie beam. The main braces also are framed into the rafter with a square toe-joint and held in place with an iron bolt, and the foot of the brace is crow-footed into the tie beam over the wall.

This truss is easily made, may be put together on the ground, and, as it is light, may be hoisted in place with blocks and tackle, with but little trouble. This truss can be made sufficiently strong to span a roof from 40 to 75 feet. Where the span inclines to the

greater length, the tie beams and rafters may be made of built-up timbers, but in such a case the tie beams should not be less than 6 x 10 inches, nor the rafters less than 6 x 6 inches.

Another style of roof altogether is shown at Fig. 63. This is a self-supporting roof, but is somewhat expensive if intended for a building having a span of 30 feet or less. It is fairly well adapted for halls or for country churches, where a high ceiling is required and the span anywhere from 30 to 50 feet over all. It would not be safe to risk a roof of this kind on a building having a span more than 50 feet. The main features of this roof are: (1) having

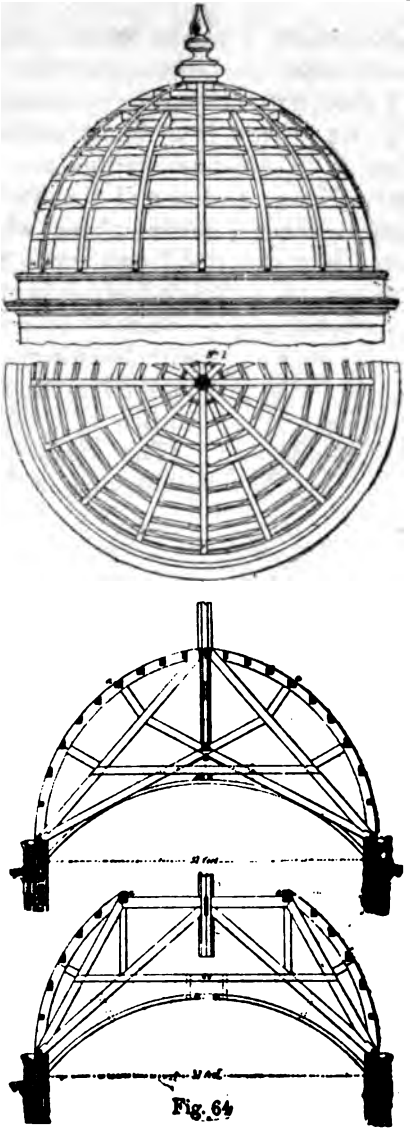


Fig. 64

collar beams, (2) truss bolts, and (3) iron straps at the joints and triple bolts at the feet.

I show a dome and the manner of its construction at Fig. 64. This is a fine example of French timber framing. The main carlins are shown at *a*, *b*, *c*, *d* and *e*, Nos. 1 and 2, and the horizontal ribs are also shown in the same numbers, with the curve of the outer edge described on them. These ribs are cut in between the carlins or rafters and beveled off to suit. This dome may be boarded over either horizontally or with boards made into "gores" and laid on in line with the rafters or carlins.

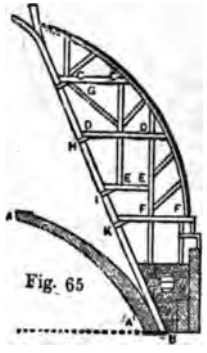


Fig. 65

The manner of framing is well illustrated in Nos. 3 and 4 in two ways, No. 3 being intended to form the two principal trusses which stretch over the whole diameter, while No. 4 may be built in between the main trusses.

The illustrations are simple and clear, and quite sufficient without further explanation.

Fig. 65 exhibits a portion of the dome of St. Paul's Cathedral, London, which was designed by Sir Christopher Wren The system of the framing of the external dome of this roof is given. The internal cupola, AA1, is of brick-work, two bricks in thickness, with a course of bricks 18 inches in length at every five feet of rise. These serve as a firm bond. This dome was turned upon a wooden center, whose only support was the projections at the springing of the dome, which is said to have been unique. Outside the brick cupola, which is only alluded to in order that the

description may be the more intelligible, rises a brickwork cone B. A portion of this can be seen, by a spectator on the floor of the cathedral, through the central opening at A. The timbers which carry the external dome rest upon this conical brickwork. The horizontal hammer beams, C, D, E, F, are curiously tied to the corbels, G, H, I, K, by iron cramps, well bedded with lead into the corbels and bolted to the hammer beams. The stairs, or ladders, by which the ascent to the Golden Gallery or the summit

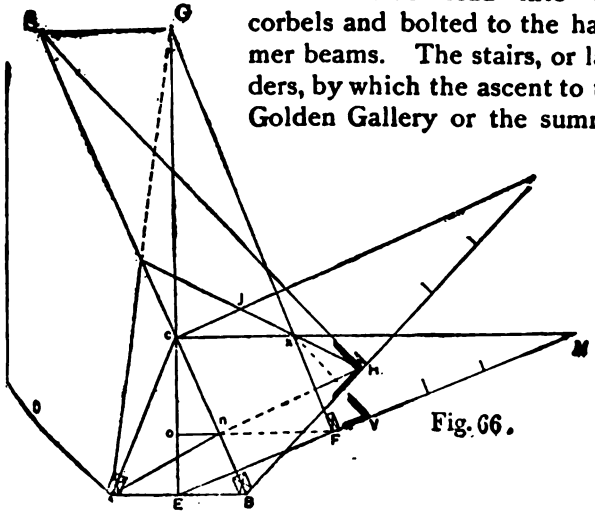


Fig. 66.

of the dome is made, pass among the roof trusses. The dome has a planking from the base upwards, and hence the principals are secured horizontally at a little distance from each other. The contour of this roof is that of a pointed dome or arch, the principals being segments of circles; but the central opening for the lantern, of course, hinders these arches from meeting at a point. The scantling of the curved principals is 10 x 11½ inches at the base, decreasing to 6 x 6 inches

at the top. A lantern of Portland stone crowns the summit of the dome. The method of framing will be clearly seen in the diagram. It is in every respect an excellent specimen of roof construction, and is worthy of the genius and mathematical skill of a great workman.

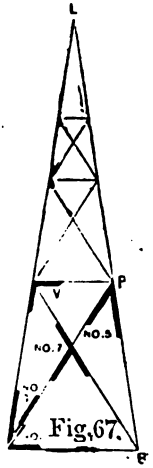


Fig. 67.

With the rules offered herewith for the construction of an octagonal spire, I close the subject of roofs: To obtain bevels and lengths of braces for an octagonal spire, or for a spire of any number of sides, let AB, Fig. 66, be one of the sides. Let AC and BC be the seat line of hip. Let AN be the seat of brace. Now, to find the position of the tie beam on the hips so as to be square with the boarding, draw a line through C, square with AB, indefinitely. From C, and square with EC, draw CM, making it equal to the height. Join EM. Let OF be the height of the tie beam. At F draw square with EM a line, which produce until it cuts EC prolonged at G. Draw CL square with BC. Make CL in length equal to EM. Join BL, and make NH equal to OF. From G draw the line GS parallel with AB, cutting BC prolonged, at the point S; then the angle at H is the bevel on the hip for the tie beam. For a bevel to miter the tie beam, make FV equal ON. Join VX; then the bevel at V is the bevel on the face. For the down bevel see V, in Fig. 67. To find the length of brace, make AB, Fig. 67, equal to AB, Fig. 66. Make AL and BL equal to BL, Fig. 66. Make BP equal to BH. Join AP and BC, which will be the length of the brace. The bevels numbered 1, 3, 5 and 7 are all to be

used, as shown on the edge of the brace. No. 1 is to be used at the top above No. 5. For the bevel on the face to miter on the hip, draw AG, Fig. 66, cutting BS at J. Join JH. Next, in Fig. 68, make AP equal AP, Fig. 67, and make AJ equal to AJ, Fig. 66. Make PJ equal to JH, Fig. 66, and make PI equal to HI. Join AI; then the bevel marked No. 5 will be correct for the beam next to the hip, and the bevel marked No. 6 will be correct for the top. Bevel No. 2 in this figure will be correct for the beam next to the plate. The edge of the brace is to correspond with the boarding.

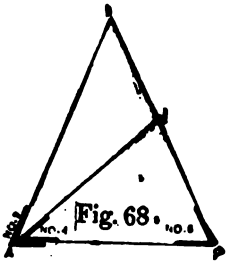
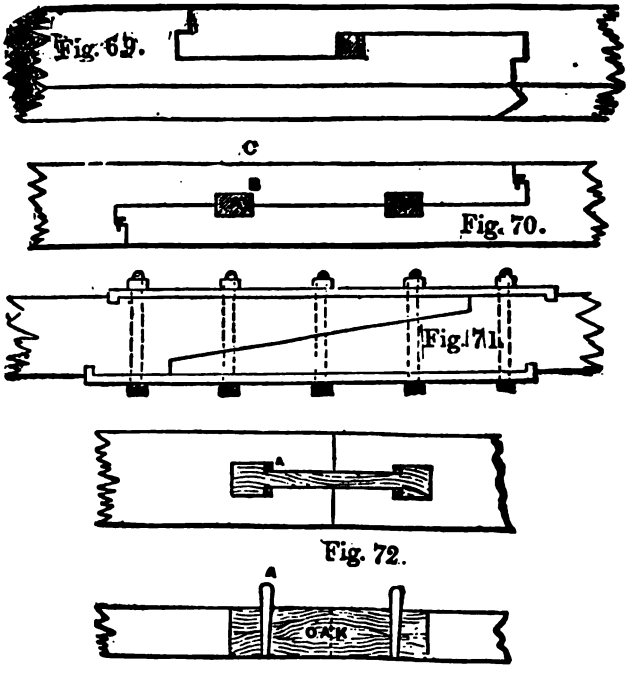


Fig. 68.

A few examples of scarfing timber are presented at Figs. 69, 70, 71 and 72. The example shown at Fig. 69 exhibits a method by which the two ends of the timber are joined together with a step-splice and spur or tenon on end, it being drawn tight together by the keys, as shown in the shaded part. Fig. 70 is a similar joint though simpler, and therefore a better one; A, A are generally joggles of hardwood, and not wedged keys, but the latter are preferable, as they allow of tightening up. The shearing used along BF should be pine, and be not less than six and a half times BC; and BC should be equal to at least twice the depth of the key. The shear in the keys being at right angles to the grain of the wood, a greater stress per square inch of shearing area can be put upon them than along BF, but their shearing area should be equal in strength to the other parts of the joint; oak is the best wood for them, as its shearing is from four to five times that of pine.

Scarfed joints with bolts and indents, such as that shown at Fig. 71, are about the strongest of the kind. From this it will be seen that the strongest and most economical method in every way, in lengthening ties, is by adoption of the common scarf joint, as shown at Fig. 71, and finishing the scarf as there represented.

The carpenter meets with many conditions when timbers of various kinds have to be lengthened out



and spliced, as in the case of wall plates, etc., where there is not much tensile stress. In such cases the timbers may simply be halved together and secured with nails, spikes, bolts, screws or pins, or they may

be halved or beveled as shown in Fig. 72, which, when loarded above, as in the case of wall plates built in the wall, or as stringers on which partitions are set, or joint beams on which the lower edges of the joists rest, will hold good together.

Treadgold gives the following rules, based upon the relative resistance to tension, crushing and shearing of different woods, for the proportion which the length or overlap of a scarf should bear to the depth of the tie:

	Without bolts	With bolts	With bolts and indents
Oak, ash, elm, etc. . .	6	3	2
Pine and similar woods .	12	6	4

There are many other kinds of scarfs that will occur to the workman, but it is thought the foregoing may be found useful on special occasions.

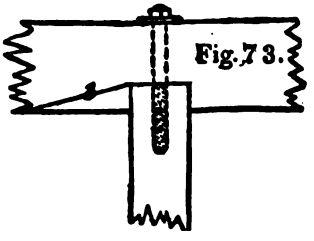


Fig. 73.

A few examples of odd joints in timber work will not be out of place. It sometimes happens that cross-beams are required to be fitted in between girders in position, as in renewing a defective one, and when this has to be done, and a mortise and tenon joint is used, a chase has to be cut leading into the mortise, as shown in the horizontal section, Fig 73. By inserting the tenon at the other end of the beams into a mortise cut so as to allow of fitting it in at an angle, the tenon can be slid along the chase *b* into its proper position. It is better in this case to dispense with the long tenon, and, if necessary, to substitute a bolt, as shown in the sketch. A mortise of this kind is called a *chase mortise*, but an

iron shoe made fast to the girder forms a better m
of carrying the end of a cross-beam. The beams
be secured to the shoe with bolts or other fasten

To support the end of a horizontal beam or gi
the side of a post, the joint shown in Fig. 74 ma

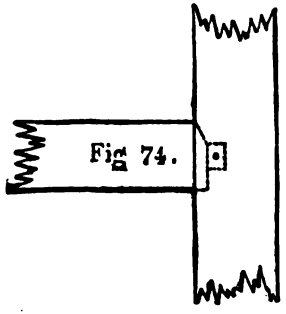


Fig. 74.

used where the mortise
the long tenon is placed
weaken the post as littl
possible, and the tenon r
about one-third the thick
of the beam on which it is
The amount of bearing
beam has on the post
greatly depend on the wc
has to do. A hardwood
can be passed through
cheeks of the mortise and the tenon as shown to
the latter in position, the holes being *draw-bor*
order to bring the shoulders of the tenon tight l
against the post, but care must be taken not to ov
the draw-boring or the wood at the end of the t
will be forced out by the
pin. The usual rule for
draw-boring is to allow a
quarter of an inch *draw* in
soft woods and one-eighth
of an inch for hard woods.

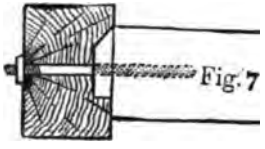


Fig. 7

These allowances may seem rather large, but it
be remembered that both holes in tenon and mc
will give a little, so also will the draw pin itself u
it is of iron, an uncommon circumstance.

Instead of a mortise and tenon, an iron strap
screw bolt or nut may be used, similiar to that sl
in Fig. 75.

The end of the beam may also be supported on a block which should be of hardwood, spiked or bolted on to the side of the post, as at A and B, Fig. 76. The end of the beam may either be tenoned into the post as shown, or it may have a shoulder, with the end of the beam beveled, as shown at A.

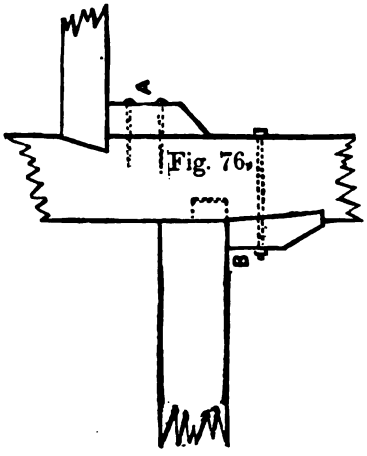


Fig. 76.

Heavy roof timbers are rapidly giving place to steel, but there yet remain many cases where timbers will remain employed and the old method of framing continued. The use of iron straps and bolts in fastening timbers together or for trussing purposes will never perhaps become obsolete, therefore a knowledge of the proper use of these will always remain valuable.

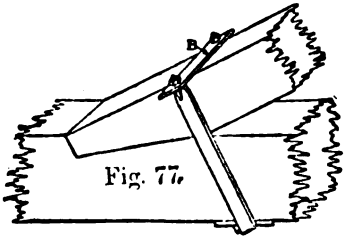


Fig. 77.

Heel straps are used to secure the joints between inclined struts and horizontal beams, such as the joints between rafters and beams. They may be placed either so as merely to hold the beams close together at the joints, as in Fig. 77, or so as to directly resist the thrust of the inclined strut and prevent it from shearing off the portion of the horizontal beam against which it presses. Straps

of the former kind are sometimes called *kicking-str*
The example shown at Fig. 77 is a good form of st
for holding a principal rafter down at the foot of
tie beam. The screws and nuts are prevented fr
sinking into the wood by the bearing plate B, wh
acts as a washer on which the nuts ride when tight
ing is done. A check plate is also provided unc
neath to prev
the strap cutt
into the tie be

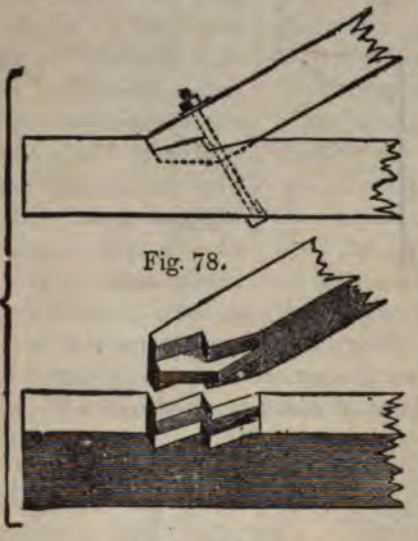


Fig. 78.

At Fig. 78 I sh
a form of jo
often used, bu
represents a d
culty in gett
the two para
abutments to t
their fair shar
the work, bo
from want of ac
racy in workm
ship as well
from the distu
ing influence
shrinkage.
making a joint of this sort, care must be taken t
sufficient wood is left between the abutments and
end of the tie beam to prevent shearing. A li
judgment in using straps will often save both t
and money and yet be sufficient for all purposes.

I show a few examples of strengthening and truss
joints, girders, and timbers at Fig 79. The diagra
need no explanation, as they are self-evident.

It would expand this book far beyond the dimensi

awarded me, to even touch on all matters pertaining to carpentry, including bridges, trestles, trussed girders and trusses generally, so I must content myself

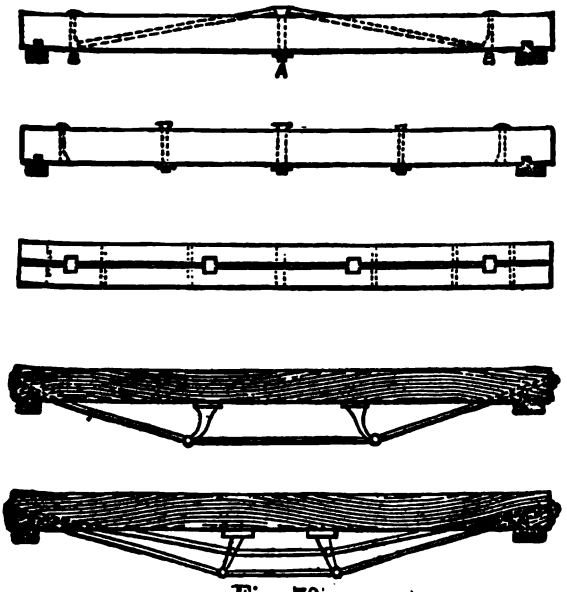


Fig. 79½

with what has already been given on the subject of carpentry, although, as the reader is aware, the subject is only surfaced.

PART III

JOINER'S WORK

CHAPTER I

KERFING, RAKING MOULDINGS, HOPPERS AND SPLAYS

This department could be extended indefinitely, as the problems in joinery are much more numerous than in carpentry, but as the limits of this book will not permit me to cover the whole range of the art, even if I were competent, I must be contented with dealing with those problems the workman will most likely be confronted with in his daily occupation.

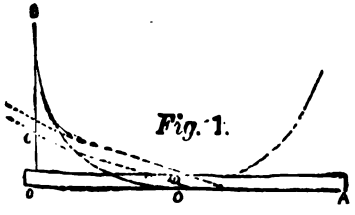


Fig. 1.

First of all, I give several methods of "kerfing," for few things puzzle the novice more than this little problem. Let us suppose any circle around which it is desired to bend a piece of stuff to be 2 inches larger on the outside than on the inside, or in other words, the veneer is to be 1 inch thick, then take out as many saw kerfs as will measure 2 inches. Thus, if a saw cuts a kerf one thirty-second of an inch in width, then it will take 64 kerfs in the half circle to allow for the

veneer to bend around neatly. The piece bei placed in position and bent, the kerfs will exact close.

Another way is to saw one kerf near the center the piece to be bent, then place it the plan of the frame, as indicated in t sketch and bend it until the kerf clos The distance, DC, Fig. 1, on the line D will be the space between the kerfs nec sary to complete the bending.

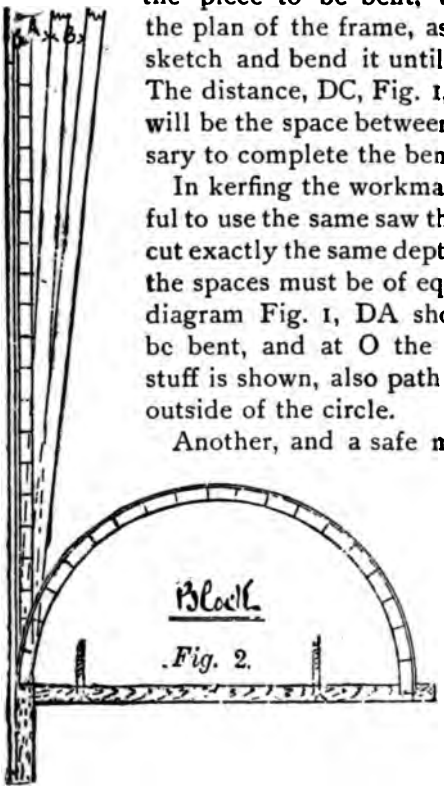


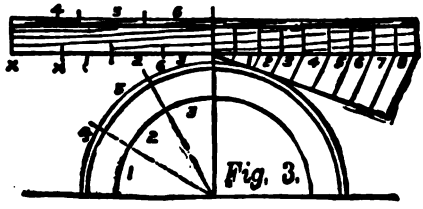
Fig. 2.

In kerfing the workman should be ca ful to use the same saw throughout, and cut exactly the same depth every time, a the spaces must be of equal distance. diagram Fig. 1, DA shows the piece bc bent, and at O the thickness of t stuff is shown, also path of the inside a outside of the circle.

Another, and a safe method of kerfi is shown at F 2, in which it desired to be a piece shown, a which is tended to secured at t ends. Up to is the piece be treate

First gauge a line on about one-eighth inch back fr the face edges, and try how far it will yield when t first cut is made up to the gauge line, being cut perfec straight through from side to side, then place the wc

on a flat board and try it gently until the kerf closes, and it goes as far as is shown at A, which is the first cut, B representing the second. Those are the distances the kerfs require to be placed apart to complete the curve. Try the work as it progresses. This eases the back of it and makes it much easier done when the whole cuts are finished. Now make certain that the job will fold to the curve, then fill them all with hot glue and proceed to fix. The plan shown here is a half semi, and may be in excess of what is wanted, but the principle holds good.



Another method is shown at Fig. 3 for determining the number and distances apart of the saw kerfs required to bend a board round a corner. The board is first drawn in position and a half of it divided into any number of equal parts by radii, as 1, 2, 3, 4, 5, 6. A straight piece is then marked off to correspond with the divisions on the circular one. By this it is seen that the part XX must be cut away by saw kerfs in order to let the board turn round. It therefore depends upon the thickness of the saw for the number of kerfs, and when that is known the distances apart can be determined as shown on the right in the figure. Here eight kerfs are assumed to be requisite.

To make a kerf for bending round an ellipse, such as that shown at Fig. 4, proceed as shown, CC and OO being the distances for the kerfs; 2 to 2 and 2 to 3 are the lengths of the points EF, while BB is the length of the

points EE, making the whole head piece in one. In case it is necessary to joint D, leave the ends about 8 inches longer than is necessary, as shown by N in the

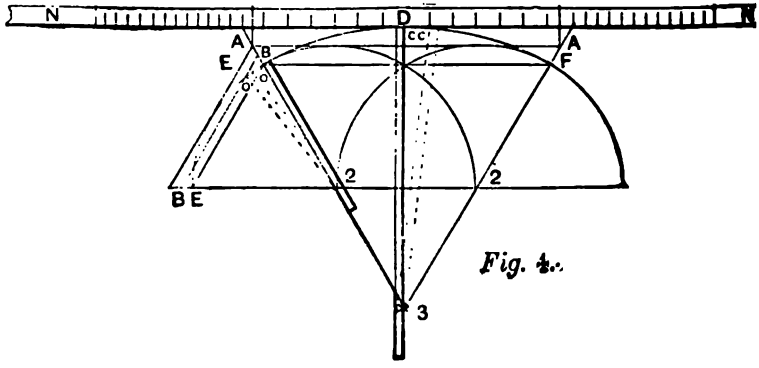


Fig. 4.

sketch, so that should a breakage occur this extra length may be utilized.

It is sometimes necessary to bend thick stuff around work that is on a rake, and when this is required, all that is necessary is to run in the kerfs the angle of the rake whatever that may be, as shown at Fig. 5. This rule holds good for all pitches or rakes. Fig. 6 shows a very common way of obtaining the distance to place the kerfs. The piece to be kerfed is shown at C; now make one at E; hold firm the lower part of C and bend

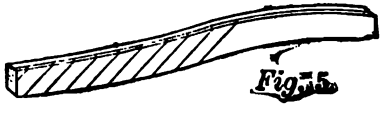
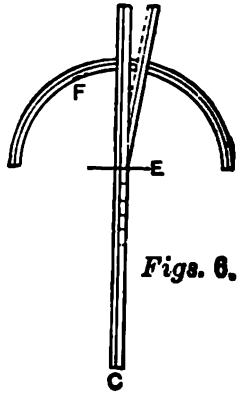
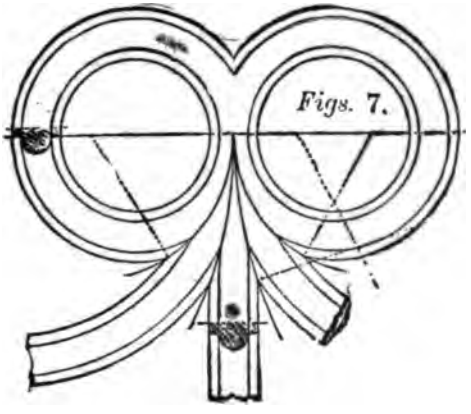


Fig. 5.



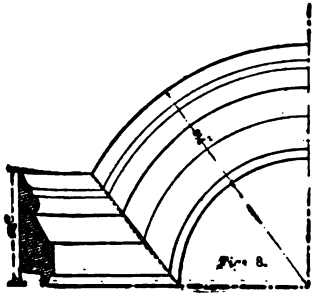
Figs. 6.

the upper end on the circle F until the kerf is closed. The line started at E and cutting the circumference of the circle indicates at the circumference the distance the saw kerfs will be apart. Set the dividers to this space, and beginning at the center cut, space the piece to be kerfed both ways. Use the same saw in all cuts and let it be clean and keen, with all dust well cleaned out.



Figs. 7.

To miter mouldings, where straight lines must merge into lines having a curvature as in Figs. 7 and 8: In all cases, where a straight moulding is intersected with a curved moulding of the same profile at whatever angle, the miter is necessarily other than a straight line. The miter line is found by the intersection of lines from the several points of the profile as they occur respectively in the straight and the curved mouldings. In order to find the miter between two such mouldings, first project lines from all of the points of



the profile indefinitely to the right, as shown in the elevation of the sketch. Now, upon the center line of the curved portion, or upon any line radiating from the center around which the curved moulding is to be carried, set off the several points of the profile, spacing them exactly the same as they are in the elevation of the straight moulding. Place one leg of the dividers at the center of the circle, bringing the other leg to each of the several points upon the curved moulding, and carry lines around the curve, intersecting each with a horizontal line from the corresponding point of the level moulding. The dotted line drawn through the intersections at the miter shows what must be the real miter line.

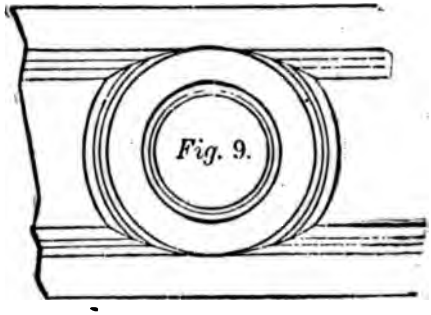


Fig. 9.

Another odd mitering of this class is shown in Fig. 9. In this it will be seen that the plain faces of the stiles and circular rail form junctions, the mouldings all being mitered. The miters are curved in order

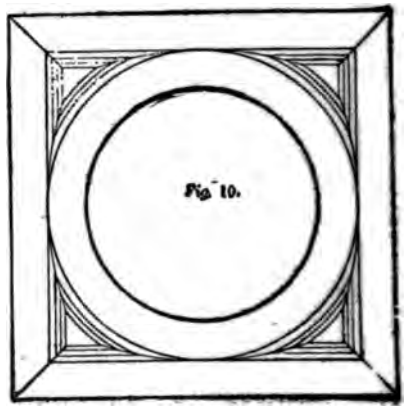


Fig. 10.

to have all the members of the mouldings merge in one another without overwood. Another example is shown at Fig. 10, where the circle and mouldings make a series of panels. These examples are quite sufficient to enable the workman to deal effectively with every problem of this kind.

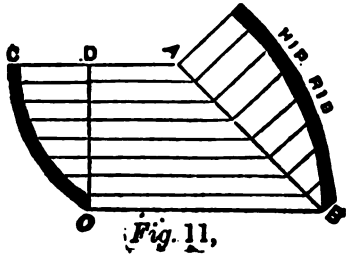


Fig. 11.

The workman sometimes finds it a little difficult to lay out a hip rafter for a veranda that has a curved roof. A very easy method of finding the curve of the hip is shown at Fig. 11. Let AB be the length of the angle or seat of hip, and CO the curve; raise perpendicular on AB, as shown, same as those on DO, and trace through the points obtained, and the thing is done.

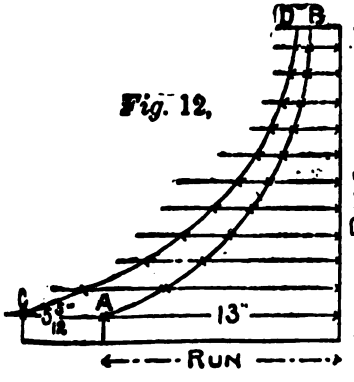


Fig. 12.

Another simple way of finding the hip for a single curve is shown at Fig. 12; AB represents the curve given the common rafter.

Now lay off any number of lines parallel with the seat from the rise, to and beyond the curve AB, as shown, and for each inch in length of these lines (between rise and curve), add $\frac{5}{12}$ of an inch to the same line to the left of the curve, and check. After

all lines have thus been measured, run an ofl curve through the checks, and the curve will rep the corresponding hip at the center of its back.

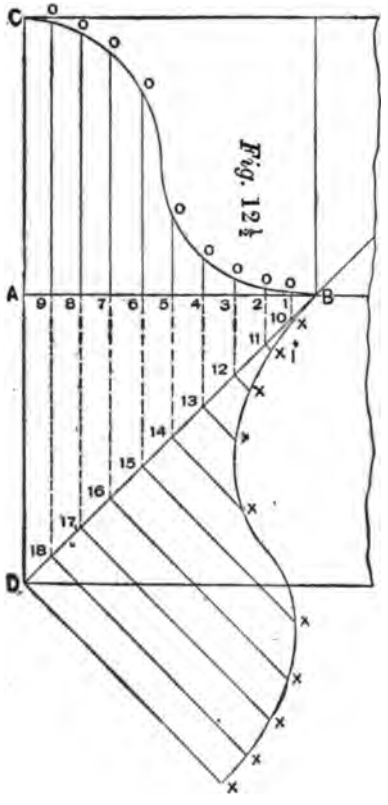


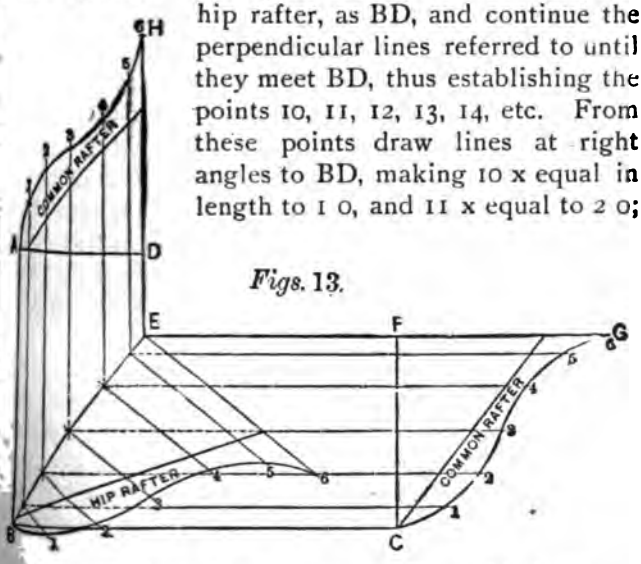
Fig. 12½

To find the or backing of t to coincide wit plane of the co rafter, measure on the parallel to the right (curve one-hal thickness of th and draw ai curve, which w the lines on th to trim to fro center of the A like amount be added to plumb cut to corner of deck. ceed in like m for the octago but instead of a $\frac{5}{12}$, add $\frac{1}{12}$ of ai as before descr

[While th worked out on en rise and run rafter, the rule is applicable to any rise or run, workman will readily understand.]

A more elaborate system for obtaining the curv hip rafter, where the common rafters have an o concave and convex shape, is shown at Fig. 12½.

a very old method, and is shown—with slight variations—in nearly all the old works on carpentry and joinery. Draw the seat of the common rafter, AB, and rise, AC. Then draw the curve of the common rafter, CB. Now divide the base line, AB, into any number of equal spaces, as 1, 2, 3, 4, 5, etc., and draw perpendicular lines to construct the curve CB, as 10, 20, 30, 40, etc. Now draw the seat of the valley, or hip rafter, as BD, and continue the perpendicular lines referred to until they meet BD, thus establishing the points 10, 11, 12, 13, 14, etc. From these points draw lines at right angles to BD, making 10 x equal in length to 1 0, and 11 x equal to 2 0;



Figs. 13.

also 12 x equal to 3 0, and so on. When this has been done draw through the points indicated by x the curve, which is the profile of the valley rafters.

Another method, based on the same principles as Fig. 12½, is shown at Fig. 13. Let ABCFED represent the plan of the roof. FCG represents the profile of the side of common rafter. First divide this common rafter, GC, into any number of parts—in this case 6.

all lines have thus been measured, run an off-hand curve through the checks, and the curve will represent the corresponding hip at the center of its back.

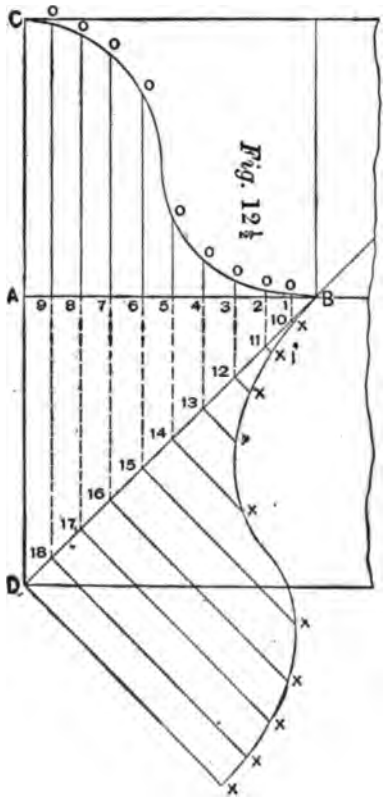


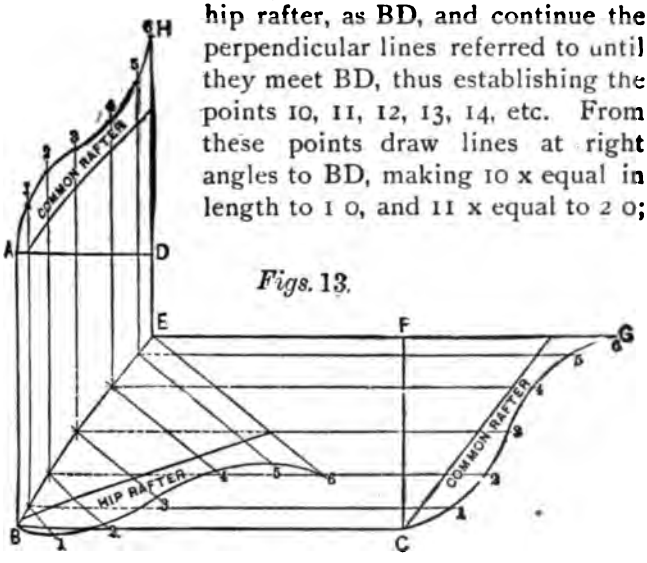
Fig. 12½

To find the bevel or backing of the hip to coincide with the plane of the common rafter, measure back on the parallel lines to the right of the curve one-half the thickness of the hip and draw another curve, which will be the lines on the side to trim to from the center of the back. A like amount must be added to the plumb cut to fit the corner of deck. Proceed in like manner for the octagon hip, but instead of adding $\frac{5}{16}$, add $\frac{3}{8}$ of an inch as before described.

[While this is worked out on a given rise and run for the rafter, the rule is applicable to any rise or run, as the workman will readily understand.]

A more elaborate system for obtaining the curve of a hip rafter, where the common rafters have an ogee or concave and convex shape, is shown at Fig. 12½. This

is a very old method, and is shown—with slight variations—in nearly all the old works on carpentry and joinery. Draw the seat of the common rafter, AB, and rise, AC. Then draw the curve of the common rafter, CB. Now divide the base line, AB, into any number of equal spaces, as 1, 2, 3, 4, 5, etc., and draw perpendicular lines to construct the curve CB, as 1 0, 2 0, 3 0, 4 0, etc. Now draw the seat of the valley, or hip rafter, as BD, and continue the perpendicular lines referred to until they meet BD, thus establishing the points 10, 11, 12, 13, 14, etc. From these points draw lines at right angles to BD, making 10 x equal in length to 1 0, and 11 x equal to 2 0;



Figs. 13.

also 12 x equal to 3 0, and so on. When this has been done draw through the points indicated by x the curve, which is the profile of the valley rafters.

Another method, based on the same principles as *Fig.* 12½, is shown at Fig. 13. Let ABCFED represent the plan of the roof. FCG represents the profile of the wide side of common rafter. First divide this common rafter, GC, into any number of parts—in this case 6.

all lines have thus been measured, run an off-hand curve through the checks, and the curve will represent the corresponding hip at the center of its back.

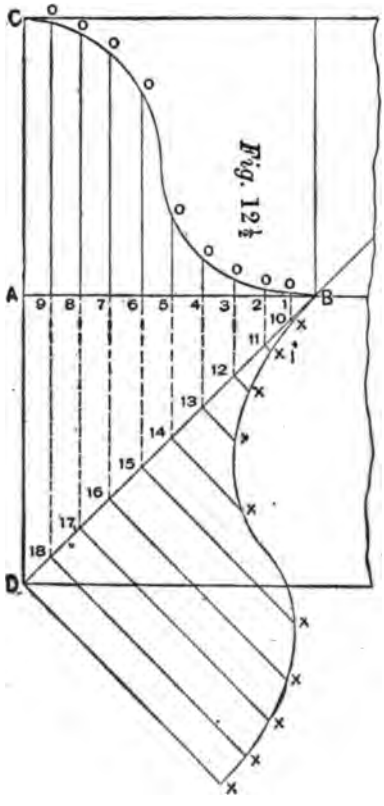


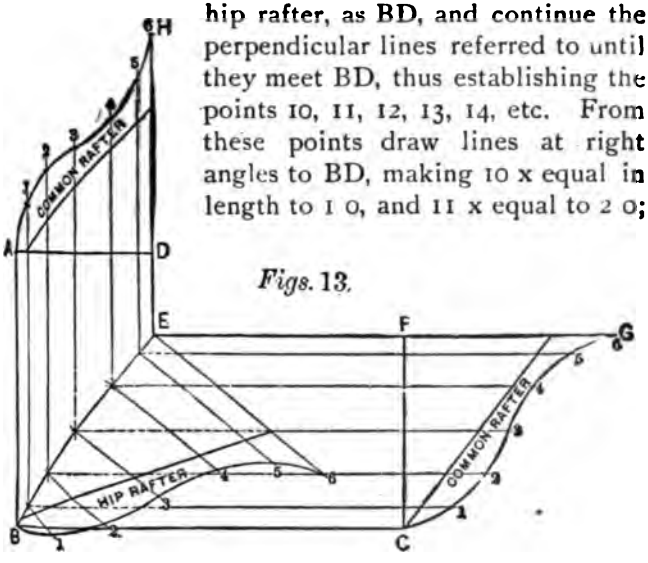
Fig. 124

To find the bevel or backing of the hip to coincide with the plane of the common rafter, measure back on the parallel lines to the right of the curve one-half the thickness of the hip and draw another curve, which will be the lines on the side to trim to from the center of the back. A like amount must be added to the plumb cut to fit the corner of deck. Proceed in like manner for the octagon hip, but instead of adding $\frac{6}{16}$, add $\frac{1}{16}$ of an inch as before described.

[While this is worked out on a given rise and run for the rafter, the rule is applicable to any rise or run, as the workman will readily understand.]

A more elaborate system for obtaining the curve of a hip rafter, where the common rafters have an ogee or concave and convex shape, is shown at Fig. 12½. This

is a very old method, and is shown—with slight variations—in nearly all the old works on carpentry and joinery. Draw the seat of the common rafter, AB, and rise, AC. Then draw the curve of the common rafter, CB. Now divide the base line, AB, into any number of equal spaces, as 1, 2, 3, 4, 5, etc., and draw perpendicular lines to construct the curve CB, as 1 0, 20, 30, 40, etc. Now draw the seat of the valley, or hip rafter, as BD, and continue the perpendicular lines referred to until they meet BD, thus establishing the points 10, 11, 12, 13, 14, etc. From these points draw lines at right angles to BD, making 10 x equal in length to 1 0, and 11 x equal to 2 0;



Figs. 13.

also 12 x equal to 3 0, and so on. When this has been done draw through the points indicated by x the curve, which is the profile of the valley rafters.

Another method, based on the same principles as Fig. 12½, is shown at Fig. 13. Let ABCFED represent the plan of the roof. FCG represents the profile of the wide side of common rafter. First divide this common rafter, GC, into any number of parts—in this case 6.

on the tangent line DE, from D, make D*d*, D*e*, D*f*, DE, respectively equal to the distances D*d*, D*e*, D*f*, DE on the level line DE, at No. 1. Through the points *d*, *e*, *f*, E, draw *da*, *eb*, *fc*, EB, then the curve drawn through the points A, *a*, *b*, *c*, B, will be the section of the circular moulding.

Sometimes mouldings for this kind of work are made of thin stuff, and are beveled on the back at the bottom in such a manner that the top portion of the member hangs over, which gives it the appearance of being solid. Mouldings of this kind are called "spring mouldings," and much care is required in mitering them. This should always be done in a miter box, which must be made for the purpose; often two boxes are required, as shown in Figs. 19-22. The cuts across the box are regular miters, while the angles down the side are the same as the down cut of the rafter, or plumb cut of the moulding. When the box is ready, place the mouldings in it upside down, keeping the moulded side to the front, as seen in Fig. 20,

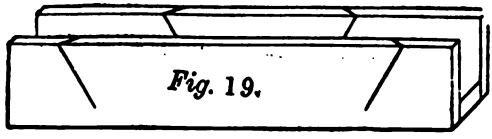


Fig. 19.

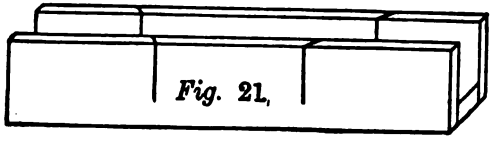


Fig. 21.

Fig. 20

Fig. 22.

making sure that the level of the moulding at *c* fits close to the side of the box.

To miter the rake mouldings together at the top, the box shown in Fig. 21 is used. The angles on the top of the box are the same as the down bevel at the top of the rafter, the sides being sawed down square. Put the moulding in the box, as shown in Fig. 22, keeping the bevel at *c* flat on the bottom of the box, and having the moulded side to the front, and the miter for the top is cut, which completes the moulding for one side of the gable. The miter for the top of the moulding for the other side of the gable may then be cut.

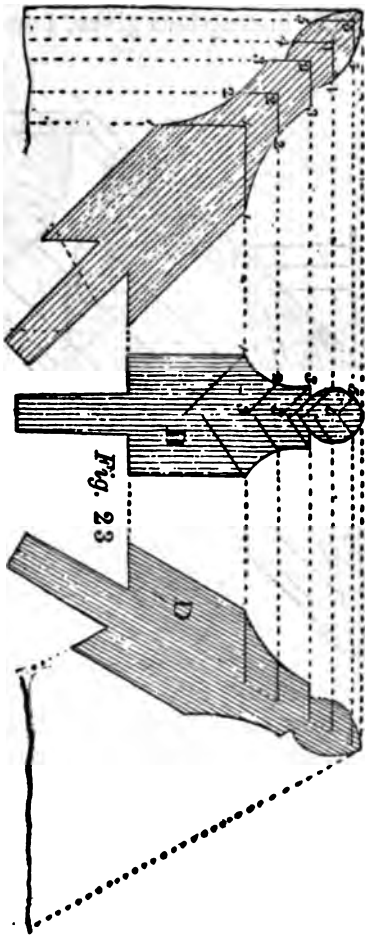


Fig. 23

When the rake moulding is made of the proper form these boxes are very convenient; but a great deal of the machine-made mouldings are

not of the proper form to fit. In such cases the moulding should be made to suit, or they come bad; although many use the mouldings as they come from the factory, and trim the miters so as to make them do.

The instructions given, however, in Figs. 13, 14, 15 and 18 will enable the workman to make patterns for what he requires.

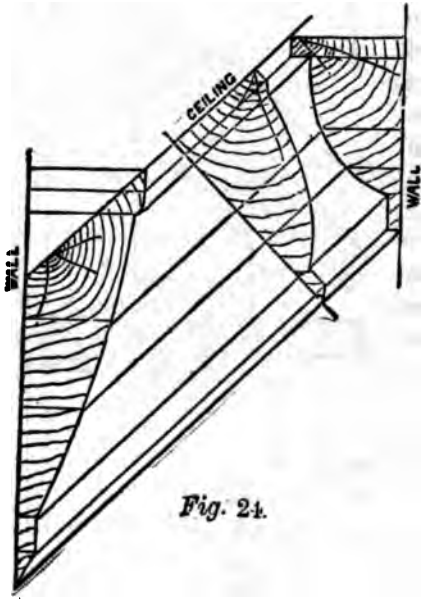


Fig. 24.

While the "angle bar" is not much in vogue at the present time, the methods by which it is obtained, may be applied to many purposes, so it is but proper the method should be embodied in this work. In Fig. 23, B is a common sash bar, and C is the angle bar of the same thickness. Take the raking projection, 11, in C, and set the foot of your compass in 1 at B, and cross the middle of the bar at the other 1; then draw the points 2, 2, 3, 3, etc., parallel to 11, then prick your bar at C from the ordinates so drawn at B, which, when traced, will give the angle bar.

This is a simple operation, and may be applied to

many other cases, and for enlarging or diminishing mouldings or other work.

The next figure, 24, gives the lines for a raking moulding, such as a cornice in a room with a sloping ceiling As may be seen from the diagram the three sections shown are drawn equal in thickness to miter at the angles of the room. The construction should be easily understood When a straight moulding is mitered with a curved one the line of miter is sometimes straight and sometimes curved, as seen at Fig. 18, and when the mouldings are all curved the miters are also straight and curved, as shown in previous examples.

Fig. 25.

If it is desired to make a cluster column of wood, it is first necessary to make a standard or core, which must have as many sides as there are to be faces of columns. Fig. 25 shows how the work is done. This shows a cluster of four columns, which are nailed to a square standard or core. Fig. 26 shows the base of a clustered column. These are blocks turned in the lathe, requiring four of them for each base, which are cut and mitered as shown in Fig. 25. The cap, or capital, is, of course, cut in the same manner.

Fig. 26.

Laying out lines for hopper cuts is often puzzling, and on this account I will devote more space to this subject than to those requiring less explanations.

Fig. 27 shows an isometric view of three sides of a hopper. The fourth side, or end, is purposely left out, in order to show the exact build of the hopper. It will be noticed that AC and EO show the end of the work as squared up from the bottom, and that BC shows the gain of the splay or flare. This gives the idea of what a hopper is, though the width of side and amount of flare may be any measurement that may be decided upon. The difficulty in this work is to get the proper lines for the miter and for a butt cut.

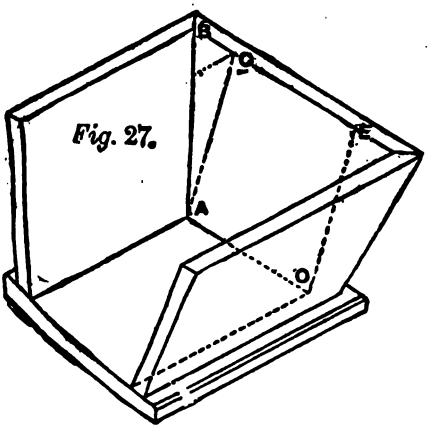


Fig. 27.

Let us suppose the flare of the sides and ends to be as shown at Fig. 28, though any flare or inclination will answer equally well. This diagram and the plan exhibit the method to be employed, where the sides and ends are to be mitered together. To obtain the bevel to apply for the side cut, use A′ as center, B′ as radius, and CDF′ parallel to BF. Project from B to D parallel to XY. Join AD, which gives the bevel required, as shown. If the top edge of the stuff is to be horizontal, as shown at B′G′, the bevel to apply to the edge will be simply as shown in plan by BG; but if

the edge of the stuff is to be square to the side, as shown at B′C′, Fig. 29, the bevel must be obtained as follows: Produce EB′ to D′, as indicated, Fig. 29. With B as center, describe the arc from C′, which gives the point D. Project down from D, making DF

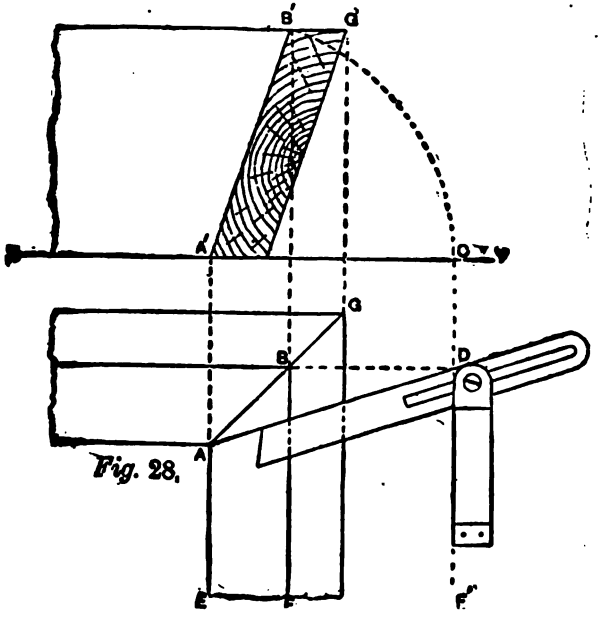


Fig. 28.

parallel to CC, as shown. Project from C parallel to XY. This will give the point D. Join BD, and this will give the bevel line required. At A, Fig. 31, is shown the application of the bevel to the side of the stuff, and at B the application of the bevel to the edge of the stuff. When the ends butt to the sides, as indicated at H, Fig. 30, the bevel, it will be noticed, is obtained in a similar manner to that shown at Fig. 28. It is not often that simply a butt joint is used between

the ends and sides, but the ends are usually housed into the sides, as indicated by the dotted lines shown at H, Fig. 30.

Another system, which was first taught by the celebrated Peter Nicholson, and afterwards by Robert Riddell, of Philadelphia, is explained in the following: The illustration shown at Fig. 32 is intended to show how to find the lines for cutting butt joints for a hopper. Construct a right angle, as A, B, C, Fig. 32, continue A, B past K. From K, B make the inclination of the sides of the hopper, 2, 3.

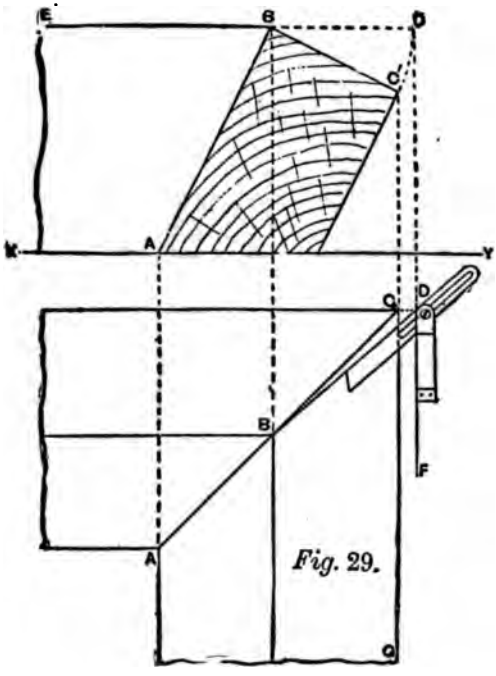


Fig. 29.

Draw 3, 4 at right angles with 3, 2; take 3 as center, and strike an arc touching the lower line, cutting in 4. Draw from 4, cutting the miter line in 5; from 5 square draw a line cutting in 6, join it and B; this gives bevel W, as the direction of cut on the surface of sides. To find the butt joint, take any two points, A, C, on the

right angle, equally distant from B, make the angle B, K, L, equal that of 3, K, L, shown on the left; from B draw through point L; now take C as a center, and strike an arc, touching line BL. From A draw a line touching the arc at H, and cutting the extended line through B in N, thus fixing N as a point. Then by drawing from C through N, we get the bevel X for the butt joint. Joints on the ends of timbers running horizontally in tapered framed structures, when the plan is square and the inclinations equal, may be found by this method.

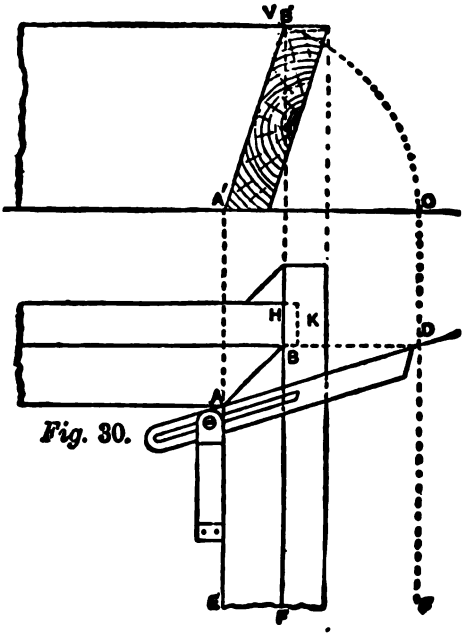


Fig. 30.

The backing of a hip rafter may also be obtained by this method, as shown at J, where the pitch line is used as at 2, 3, which would be the inclination of the roof.

The solution just rendered is intended only for hoppers having right angles and equal pitches or splays, as hoppers having acute or obtuse angles, must be treated in a slightly different way.

Let us suppose a butt joint for a hopper having an

acute angle, such as shown at A, B, C, Fig. 33, and with an inclination as shown at 2, 3. Take any two points, A, C, equally distant from B. Join A, C, bisect this line in P, draw through P, indefinitely. Find a bevel for the side cut by drawing 3, 4, square with 2, 3; take 3 as a center, and strike an arc, touching the lower line cutting in 4; draw from 4, cutting

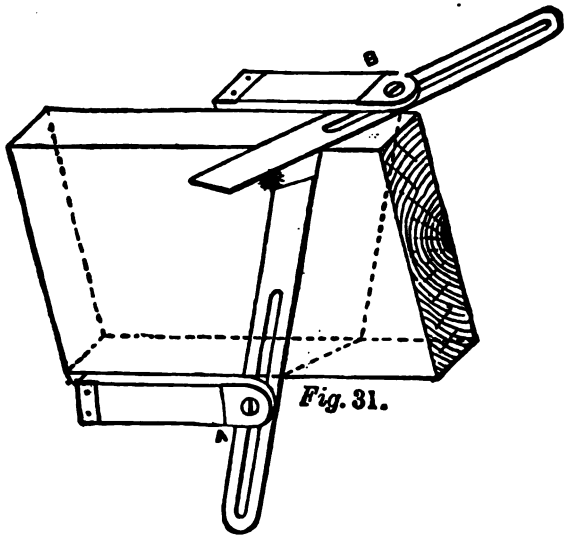


Fig. 31.

the miter line in 5, and from it square draw a line cutting in 6. Join 6, B, this gives bevel W, for direction of cut on the surface of inclined sides.

The bevel for a butt joint is found by drawing C, 8, square with A, B; make the angle 8, K, L, equal that of 3, K, L, shown on the left. Draw from 8 through point L; take C as a center and strike an arc touching the line 8, L; draw from A, touching the arc at D, cutting

the line from P, in D, making it a point, then by drawing from C, through D, we get the bevel X for the butt joint.

As stated regarding the previous illustration, the backing for a hip in a roof having the pitch as shown at 2, 3, may be found at the bevel J. The same rule

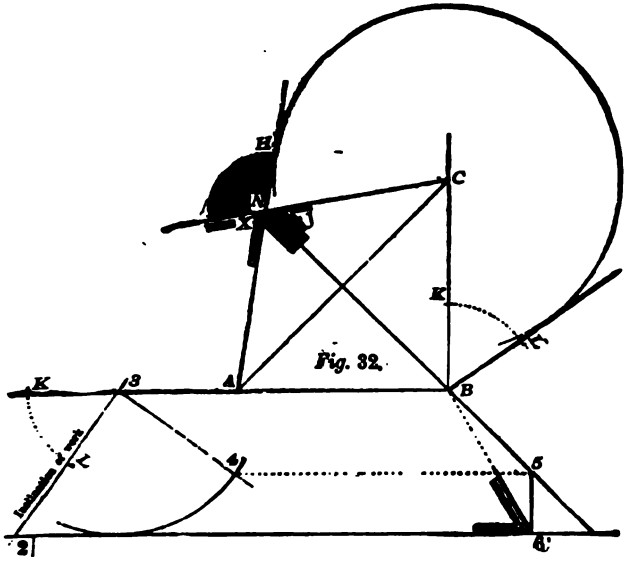


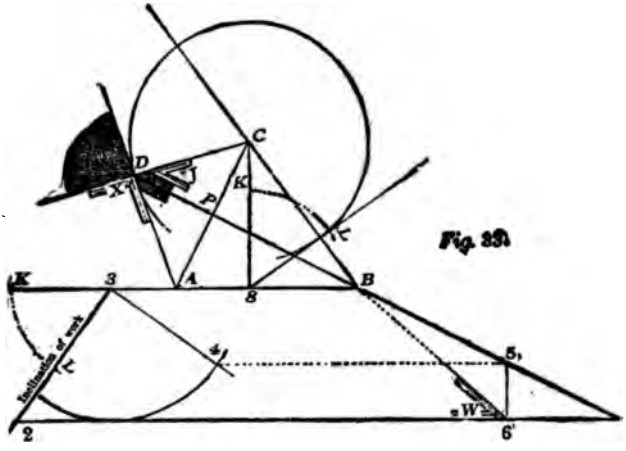
Fig. 32.

also applies to end joints on timbers placed in a horizontal double inclined frame, having an acute angle same as described.

Having described the methods for finding the butt joints in right-angled and acute-angled hoppers, it will be proper now to define a method for describing an obtuse-angled hopper having butt joints.

Let the inclination of the sides of the hopper be

exhibited at the line 2, 3, and the angle of the obtuse corner of the hopper at A, B, C, then to find the joint, take any two points, A, C, equally distant from B, join these points, and divide the line at P. Draw through P and B, indefinitely. At any distance below the side A, B, draw the line 2, 6; make 3, 4, square with the inclination. From 3, as a center, describe an arc, touching the lower line and cutting in 4; from 4 draw to cut the miter line in 5, and from it square

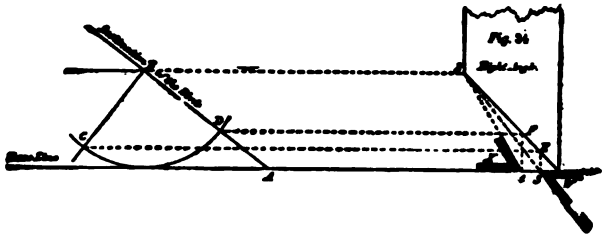


down a line cutting in 6, join 6, B, and we get the bevel W, for cut on surface sides.

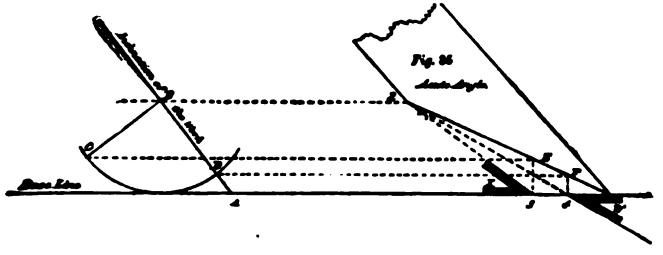
The bevel for the butt joint is found by drawing C, D, square with B, A, and making the angle D, K, L equal to that of 3, K, L on the left. From C, as a center, strike an arc, touching the line D, L; then from A draw a line touching the arc H. This line having cut through P, in N, fixes N as a point, so that by drawing C through N an angle is determined, in which is bevel X for the butt joint.

To obtain the bevels or miters is a simple matter to one who has mastered the foregoing, as evidenced by the following:

Fig. 34 shows a right-angled hopper; its sides may stand on any inclination, as AB. The miter line,



2, W, on the plan, being fixed, draw B, C square with the inclination. Then from B, as center, strike an arc, touching the base line and cutting in CD. From CD draw parallel with the base line, cutting the miters in F and E; and from these points square down the lines, cutting in 3 and 4. From 2 draw through 3; this gives

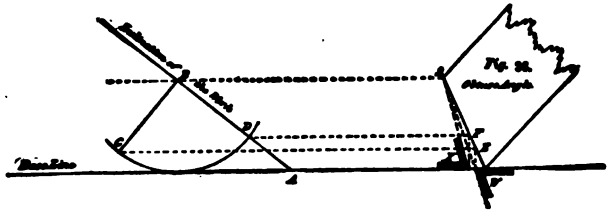


bevel W for the direction of cut on the surface sides. Now join 2, 4, this gives bevel X to miter the edges, which in all cases must be square, in order that bevels may be properly applied.

Fig. 35 shows a plan forming an acute-angled hop-

per, the miter line being 2, W. The sides of this plan are to stand on the inclination AB. Draw BC square with the inclination, and from B, as center, strike an arc, touching the base line and cutting in CD. Draw from CD, cutting the miter line at E and F; from these points square down the lines, cutting in 3 and 4. From 2 draw through 4, which will give bevel W to miter the edges of sides. Now join 2, 3, which gives bevel X for the direction of cut on the surface of sides.

Fig. 36 shows an obtuse-angled hopper, its miter line on the plan being 2 W, and the inclination of sides



AB. Draw BC square with the inclination, and from B as center strike an arc, touching the base line and cutting CD. Draw from CD, cutting the miter in F and E. From these points square down the lines, cutting the base; then by drawing from 2 through the point below E, we get bevel W for the direction of cuts on the surface of sides, and in like manner the point below F being joined with 2, gives bevel X to miter the edges.

It will be noticed that the cuts for the three different angles are obtained on exactly the same principle, without the slightest variation, and so perfectly simple as to be understood by a glance at the drawing. The workman will notice that in each of the angles a

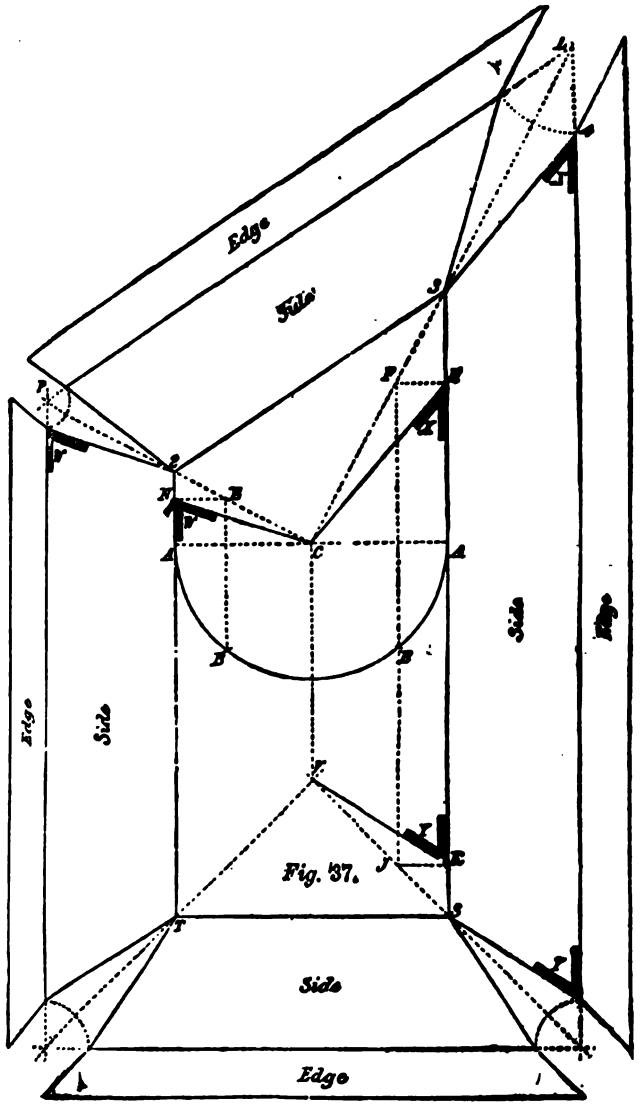


Fig. 37.

line from C, cutting the miter, invariably gives a direction for the surface of sides, and the line from D directs the miter on their edges.

Unlike many other systems employed, this one meets all and every condition, and is the system that has been employed by high class workmen and millwrights for ages.

One more example on hopper work and I am done with the subject: Suppose it is desired to build a hopper similar to the one shown at Fig. 37, several new conditions will be met with, as will be seen by an examination of the obtuse and acute angles, L and P. In order to work this out right make a diagram like that shown at Fig. 38, where the line AD is the given base line on which the slanting side of hopper or box rises at any angle to the base line, as CB, and the total height of the work is represented by the line B, E. By this diagram it will be seen that the horizontal lines or bevels of the slanting sides are indicated by the bevel Z.

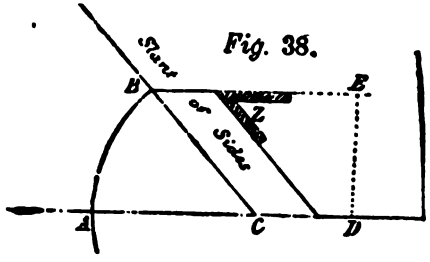


Fig. 38.

Having got this diagram, which of course is not drawn to scale, well in hand, the ground plan of the hopper may be laid down in such a shape as desired, with the sides, of course, having the slant as given in Fig 38.

Take T2, 3S, Fig. 37, as a part of the plan, then set off the width of sides equal to C, B, as shown in Fig. 38.

These are shown to intersect at P, L above; then draw lines from P, L through 2, 3, until they intersect at C, as the dotted lines show. Take C as a center, and with the radius A, describe the semi-circle A, A, and with the same radius transferred to C, Fig. 38, describe the arc A, B, as shown. Again, with the same radius, set off A, B, A, B on Fig. 37, cutting the semi-circle at B, as shown. Now draw through B, on the right, parallel with S, 3, cutting at J and F; square over F, H and J, K, and join H, C; this gives bevel X, as the cut for face of sides, which come together at the angle shown at 3. The miters on the edge of stuff are parallel with the dotted line, L, 3. This is the acute corner of the hopper, and as the edges are worked off to the bevel 2, as shown in Fig. 38, the miter must be correct.

Having mastered the details of the acute corner, the square corner at S will be next in order. The first step is to join K, V, which gives the bevel Y, for the cut on the face of sides on the ends, which form the square corners. The method of obtaining these lines is the same as that explained for obtaining them for the acute-angled corner, as shown by the dotted lines, Fig. 35. As the angles, S, T, are both square, being right and left, the same operation answers both, that is, the bevel Y does for both corners.

Coming to the obtuse angle, P, 2, we draw a line B, E, on the left, parallel with A, 2, cutting at E, as shown by dotted line. Square over at E, cutting T, A, 2 at N; join N, C, which will give the bevel W, which is the angle of cut for face of sides. The miters on edges are found by drawing a line parallel with P, 2.

In this problem, like Fig. 34, every line necessary to the cutting of a hopper after the plan as shown by

the boundary lines 2, 3, T, S, is complete and exhaustive, but it must be understood that in actual work the spreading out of the sides, as here exhibited, will not be necessary, as the angles will find themselves when the work is put together. When the plan of the base—which is the small end of the hopper in this case—is given, and the slant or inclination of the sides known, the rest may be easily obtained. In order to become thoroughly conversant with the problem, I would advise the workman to have the drawing made on cardboard, so as to cut out all the outer lines, including the open corners, which form the miters, leaving the whole piece loose. Then make slight cuts in the back of the cardboard, opposite the lines 2, 3, S, T, just deep enough to admit of the cardboard being bent upwards on the cut lines without breaking. Then run the knife along the lines, which indicates the edges of the hopper sides. This cut must be made on the face side of the drawing, so as to admit of the edges being turned downwards. After all cuts are made raise the sides until the corners come closely together, and let the edges fall level, or in such a position that the miters come closely together. If the lines have been drawn accurately and the cuts made on the lines in a proper manner, the work will adjust itself nicely, and the sides will have the exact inclination shown at Fig. 38, and a perfect model of the work will be the result.

This is a very interesting problem, and the working out of it, as suggested, cannot but afford both profit and pleasure to the young workman.

From what has preceded, it must be evident to the workman that the lines giving proper angles and bevels for the corner post of a hopper must of neces-

sity give the proper lines for the corner post for a pyramidal building, such as a railway tank frame, or any similar structure. True, the position of the post is inverted, as in the hopper, its top falls outward, while in the timber structure the top inclines inward; but this makes no difference in the theory, all the operator has to bear in mind is that the hopper in this case is reversed —inverted. Once the proper shape of the corner post has been obtained, all other bevels can readily be found, as the side cuts for joists and braces can be taken from them. A study of these two figures in this direction will lead the student up to a correct knowledge of tapered framing.

CHAPTER II

COVERING SOLIDS, CIRCULAR WORK, DOVETAILING AND STAIRS

There are several ways to cover a circular tower roof. Some are covered by bending the boarding around

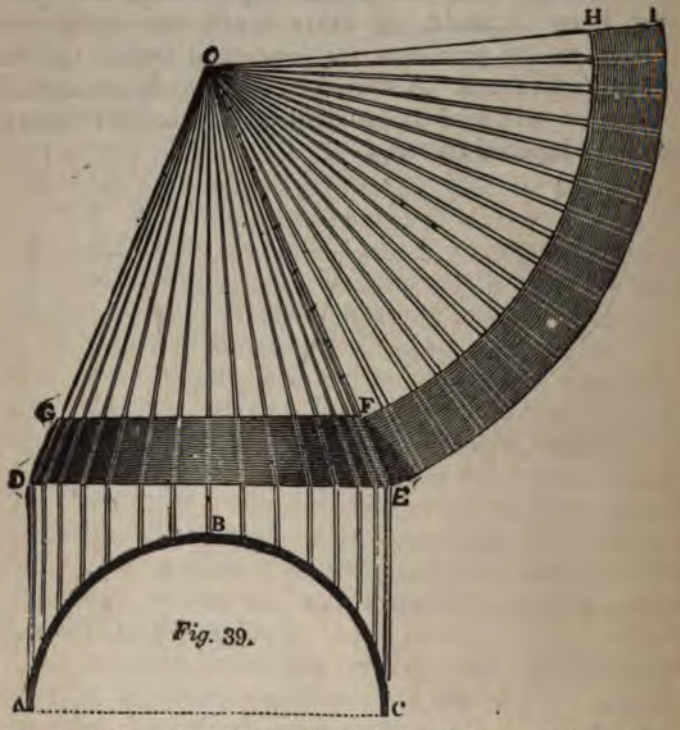


Fig. 39.

them, while others have the joints of the covering vertical, or inclined. In either case, the boarding has to be cut to shape. In the first instance, where the joints

are horizontal, the covering must be curved on both edges.

At Fig. 39 I show a part plan, elevation, and development of a conical tower roof. ABC shows half the plan; DO and EO show the inclination and height of the tower, while EH and EI show the development of the lower course of covering. This is obtained by using O as a center, with OE as radius, and striking the curve EI, which is the lower edge of the board, and corresponds to DE in the elevation. From the same center O, with radius OF, describe the curve FH, which is the joint GF on the elevation. The board, EFHI, may be any convenient width, as may also the other boards used for covering, but whatever the width decided upon, that same width must be continued throughout that course. The remaining tiers of covering must be obtained in the same way. The joints are radial lines from the center O. Any convenient length of stuff over the distance of three ribs, or rafters, will answer. This solution is applicable to many kinds of work. The rafters in this case are simply straight scantlings; the bevels for feet and points may be obtained from the diagram. The shape of a "gore," when such is required, is shown at Fig. 40, IJK showing the base, and L the top or apex. The method of getting it out will be easily understood by examining the diagram. When "gores" are used for covering it will be necessary

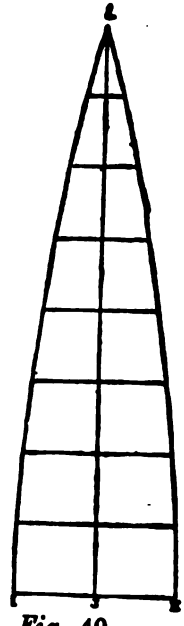


Fig. 40.

to have cross-ribs nailed in between the rafters, and these must be cut to the sweep of the circle, where they are nailed in, so that a rib placed in half way up will require only to be half the diameter of the base, and the other ribs must be cut accordingly.

To cover a domical roof with horizontal boarding we proceed in the manner shown in Fig. 41, where ABC

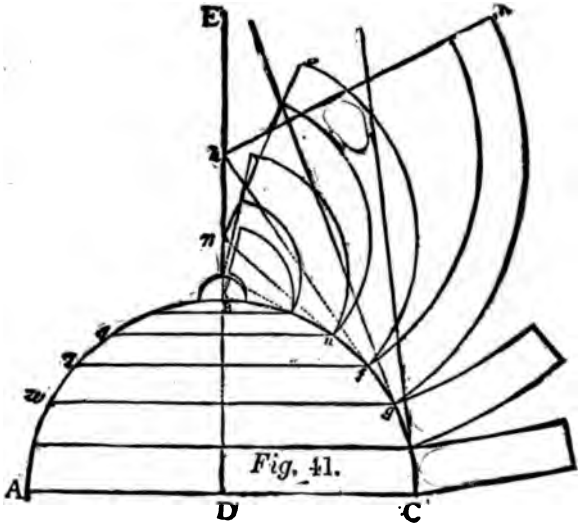


Fig. 41.

is a vertical section through the axis of a circular dome, and it is required to cover this dome horizontally. Bisect the base in the point D, and draw DBE perpendicular to AC, cutting the circumference in B. Now divide the arc, BC, into equal parts, so that each part will be rather less than the width of a board, and join the points of division by straight lines, which will form an inscribed polygon of so many sides; and through these points draw lines parallel to

the base AC, meeting the opposite sides of the circumference. The trapezoids formed by the sides of the polygon and the horizontal lines may then be regarded as the sections of so many frustrums of cones; whence results the following mode of procedure: Produce, until they meet the line DE, the lines FG, etc., forming the sides of the polygon. Then to describe a board which corresponds to the surface of one of the zones, as FG, of which the trapezoid is a section from

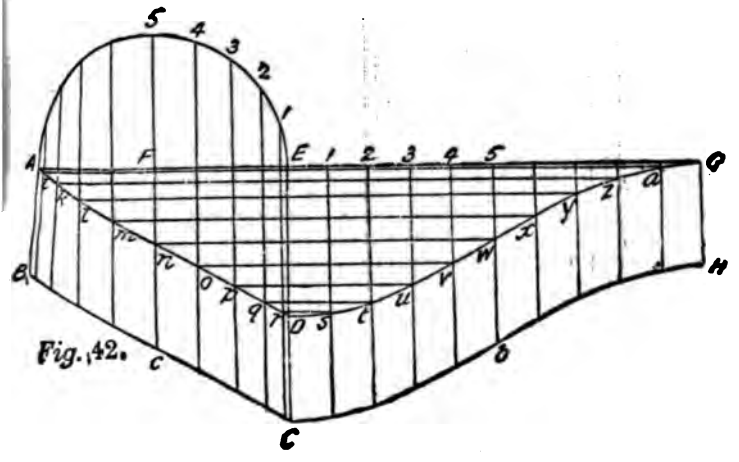


Fig. 42.

the point E, where the line FG produced meets DE, with the radii EF, EG describe two arcs and cut off the end of the board K on the line of a radius EK. The other boards are described in the same manner.

There are many other solids, some of which it is possible the workman may be called upon to cover, but as space will not admit of us discussing them all, we will illustrate one example, which includes within itself the principles by which almost any other solid

may be dealt with. Let us suppose a tower, hav
domical roof, rising from another roof having an
nation as shown at BC, Fig. 42, and we wish to l
it with the join
the boards on
same inclinati
that of the
through whicl
tower rises.
accomplish thi
A, B, C, D, Fi
be the seat o
generating se
from A draw
perpendicul
AB, and pr
CD to meet it
on A, E descril
semi-circle,
transfer its p
eter to E,
dividing it
equal parts,
setting off
sponding div
on E, G. Th
the divisions c
semi-circle
lines at right a
to AE, prod
them to mee

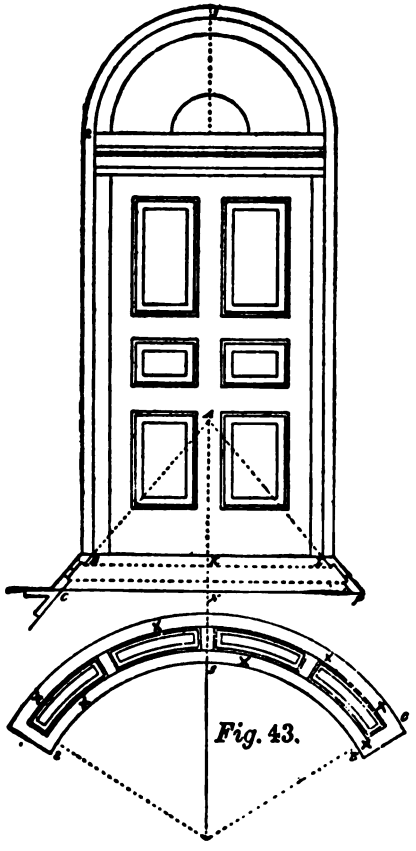


Fig. 43.

lines A, D and B, C in *i*, *k*, *l*, *m*, etc. Throug
divisions on E, G, draw lines perpendicular to
then through the intersections of the ordinates c

semi-circle, with the line AD draw the lines *i*, *a*, *k*, *s*, *l*, *y*, etc., parallel to AG, and where these intersect the perpendiculars from EG, in points *a*, *s*, *y*, *x*, *w*, *v*, *u*, etc., trace a curved line, GD, and draw parallel to it the curved line HC; then will DC, HG be the development of the covering required.

Almost any description of dome, cone, ogee or other solid may be developed, or so dealt with under the principle as shown in the foregoing, that the workman, it is hoped, will experience but little difficulty in laying out lines for cutting material to cover any form of curved roof he may be confronted with.

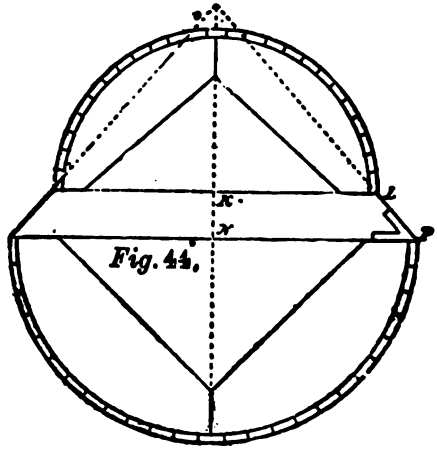


Fig. 44.

Another class of covering is that of making soffits for splayed doors or windows having circular or segmental heads, such as shown in Fig. 43, which exhibits a door with a circular head and splayed jambs. The head or soffit is also splayed and is paneled as shown. In order to obtain the curved soffit, to show the same splay or angle, from the vertical lines of the door, proceed as follows: Lay out the width of the doorway, showing the splay of the jambs, as at C, B and L, P; extend the angle lines, as shown by the dotted lines, to A, which gives A, B as the radius of the

inside curve, and A, C as radius of the outside curve. These radii correspond to the radii A, B and A, C in Fig. 43; the figure showing the flat plan of the paneled soffit complete. To find the development, Fig. 43, get the stretch-out of the quarter circle 2 and 3, shown in the elevation at the top of the doorway, and

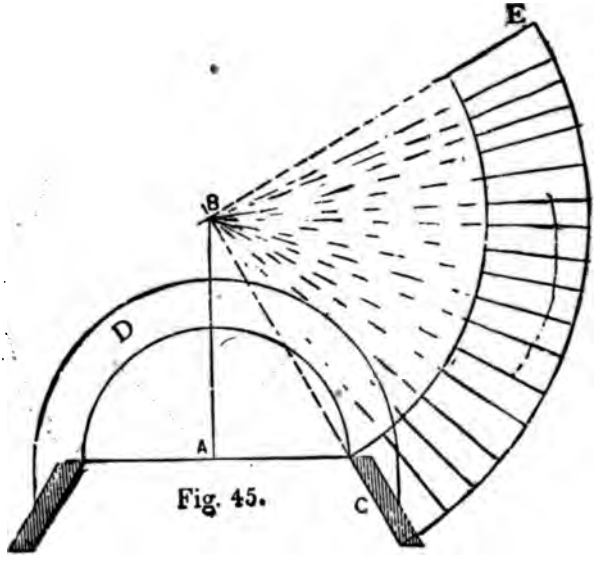


Fig. 45.

make 2, 3 and 3B, Fig. 43, equal to it, and the rest of the work is very simple.

If the soffit is to be laid off into panels, as shown at Fig. 44, it is best to prepare a veneer, having its edges curved similar to those of Fig. 43, making the veneer of some flexible wood, such as basswood, elm or the like, that will easily bend over a form, such as is shown at Fig. 44. The shape of this form is a portion of a cone, the circle L being less in diameter than the

circle P. The whole is covered with staves, which, of course, will be tapered to meet the situation. The veneer, x, x, etc., Fig. 43, may then be bent over the form and finished to suit the conditions. If the mouldings used in the panel work are bolection mouldings, they cannot be planted in place until after the veneer is taken off the form.

This method of dealing with splayed work is applicable to windows as well as doors, to circular pews in

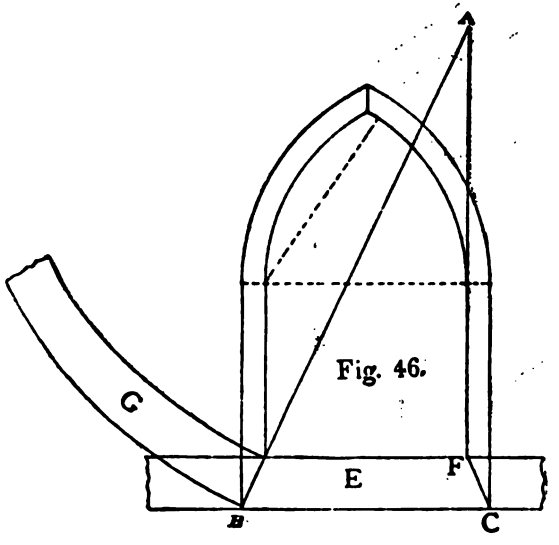


Fig. 46.

churches and many other places where splayed work is required.

A simple method of finding the veneer for a soffit of the form shown in Fig. 43 is shown at Fig. 45. The splay is seen at C, from which a line is drawn on the angle of the splay to B through which the vertical line A passes. B forms the center from which the veneer

is described. A is the center of the circular head, for both inside and outside curves, as shown at D. The radial lines centering at B show how to kerf the stuff when necessary for bending. The line E is at right angles with the line CB, and the veneer CE is the proper length to run half way around the soffit. The joints are radial lines just as shown.

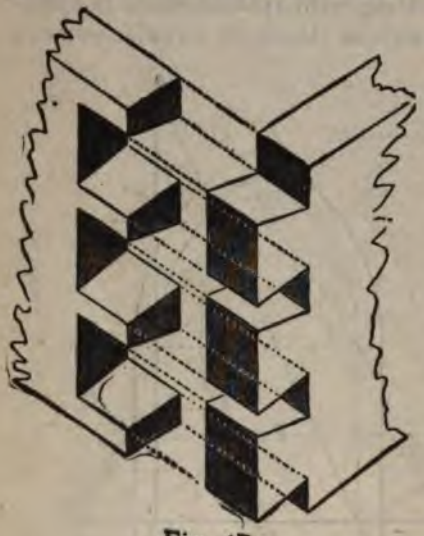


Fig. 47.

A method for obtaining the correct shape of a veneer for a gothic splayed window or door-head, is shown at Fig. 46; E shows the sill, and line BA the angle of splay. BC shows the outside of the splay; erect the inside line F to A, and this point will form the center from which to describe the curve or veneer G. This veneer will be the proper shape to bend in the soffit on either side of the window head.

The art of dovetailing is almost obsolete among carpenters, as most of this kind of work is now done by cabinet-makers, or by a few special workmen in the factories. It will be well, however, to preserve the art, and every young workman should not rest until he can do a good job of work in dovetailing; he will not find it a difficult operation.

There are three kinds of dovetailing, i.e., the common dovetail, Fig. 47; the lapped dovetail, Fig. 48, and the secret, or mitered dovetail, Fig. 49. These may be subdivided into other kinds of dovetailing, but there will be but little difference.

The common dovetail is the strongest, but shows the ends of the dovetails on both faces of the angles,

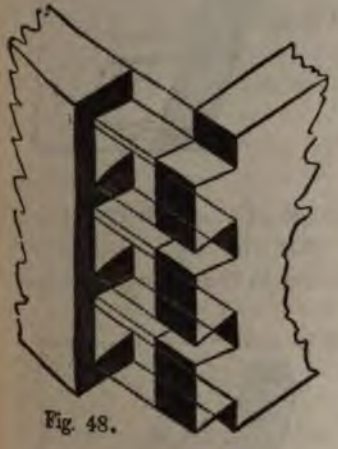


Fig. 48.

Fig. 49.

and is, therefore, only used in such places as that of a drawer, where the external angle is not seen.

The lapped dovetail, where the ends of the dovetails show on one side of the angle only, is used in such places as the front of a drawer, the side being only seen when opened.

In the miter or secret dovetail, the dovetails are not seen at all. It is the weakest of the three kinds.

At Figs. 50 and 51 I show two methods of dovetailing hoppers, trays and other splayed work. The reference letters A and B show that when the work is together A will stand directly over B. Care must be

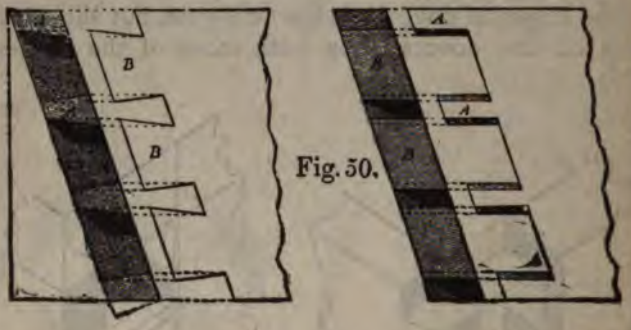


Fig. 50.

taken when preparing the ends of stuff for dovetailing for hoppers, trays, etc., that the right bevels and angles are obtained according to the rules explained

Fig. 51.

for finding the cuts and bevels for hoppers and work of a similar kind, in the examples given previously. All stuff for hopper work intending to be dovetailed

must be prepared with butt joints before the dovetails are laid out. Joints of this kind may be made common, lapped or mitered. In making the latter much skill and labor will be required.

Stair building and handrailing combined is a science in itself, and one that taxes the best [illegible] the market, and it will be impossible [illegible] more than touch the subject, and that [illegible] enable the workman to lay [illegible] flight of stairs. For further [illegible] building I would refer my [illegible] two of the many works on the [illegible] obtained from any dealer in [illegible] books.

The first thing the stair builder has [illegible] dimension of the space the stairs are [illegible] he must get the height, or the risers and [illegible] the treads, and, as architects generally [illegible] of the stairs, showing the space they are [illegible] and the number of treads, the stair builder has [illegible] measure the height from floor to floor and [illegible] the number of risers and the distance from first to [illegible] riser, and divide by the number of treads. [illegible] refers only to straight stairs.) Let us take an example: Say that we have ten feet of height and fifteen feet ten inches of run, and we have nineteen treads: thus fifteen feet ten inches divided by nineteen gives us ten inches for the width of the tread, and we have ten feet rise divided by twenty (observe here that there is always one more riser than tread), which gives us six inches for the height of the riser. The pitch-board must now be made, and as all the work has to be set out from it, care must be taken to make it exactly right. Take a piece of board, same as shown

in Fig. 52, about half an inch thick, dress it and square the side and end, A, B, C; set off the height of the rise from A to B, and the width of the tread from B to C; now cut the line AC, and the pitch-board is complete, as shown in Fig. 53. This may be done by the steel square as shown at Fig. 54. To get the width of string-boards draw the line AB, Fig. 53; add to the length of this line about half an inch more at A, the margin to be allowed, and the total will be the width of string-boards. Thus, say that we allow three inches

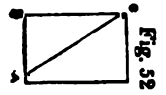


Fig. 52.

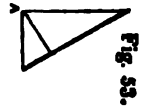


Fig. 53.

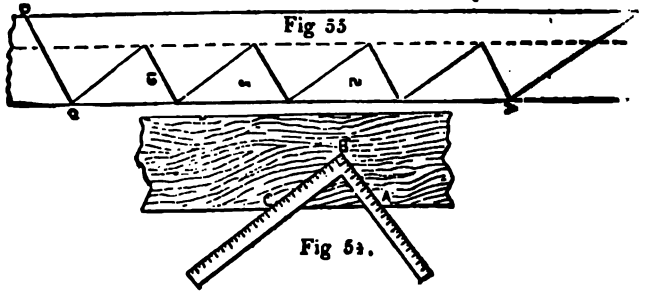


Fig 55

Fig 54.

for margin, one-half inch to be left on the under of string-board, will make the width of string-l in this case about nine inches. Now get a pla one and a half inches, of any thickness that agreed upon, the length may be obtained by m ing the longest side of the pitch-boards, AC, by the number of risers; but as this is the only stairs that the length of string-boards can be in this way I would recommend the beginne tice the sure plan of taking the pitch-board a ing it as at 1, 2, 3, 19, Fig. 55. Drawing al

this way will prevent a mistake that sometimes occurs, viz. the string-boards being cut too short. Cut the foot at the line AB, and the top, as at CD. This will give about one and a half inches more than the extreme length. Now cut out the treads and risers; the width of stair is, say, three feet, and we have one and a half inches on each side for string-boards. Allow three-eights of an inch for housing on each side. This will make the length of tread and risers two and one-fourth inches less than the full width of stairs; and as the treads must project their own thickness over rise, which is, say, one and a half inches, the full size of tread will be two feet by eleven and one-half inches, and of the risers two feet nine and three-fourths inches by six inches; and observe that the first riser will be the thickness of the tread less than the others; it will be only four and one-half inches wide. The reason of this riser being less than the others is because it has a tread thickness extra.

I will now leave the beginner to prepare all his work. Dress the risers on one face and one edge; dress the treads on one face and both edges, making them all of equal width; gauge the ends and the face edge to the required thickness, and round off the nosings; dress the string-boards to one face and edge to match each other.

A plan of a stair having 13 risers and three winders below is shown at Fig. 56. This shows how the whole stair may be laid out. It is inclosed between two walls.

The beginner in stair-work had better resort to the old method of using a story-rod for getting the number of risers. Take a rod and mark on it the exact height from top of lower floor to top of next floor, then

divide up and mark off the number of risers required There is always one more riser than tread in ever flight of stairs. The first riser must be cut the thickness of the tread less than the others.

When there are winders, special treatment will b

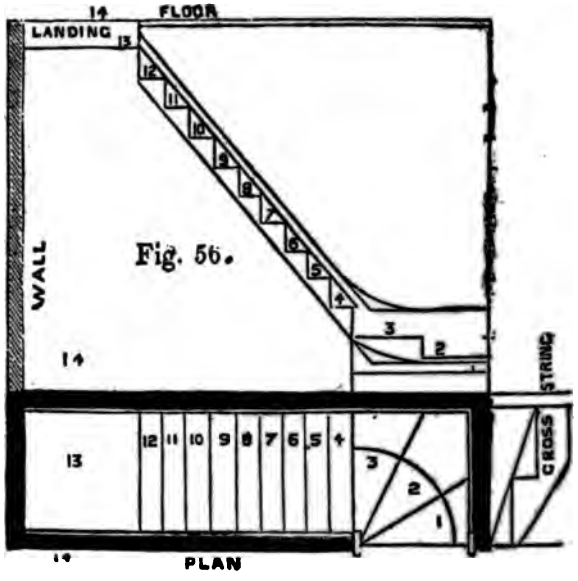


Fig. 56.

required, as shown in Fig. 56, for the treads, but th riser must always be the same width for each separat flight.

When the stair is straight and without winders, rod may be used for laying off the steps. The widt of the steps, or treads, will be governed somewhat b the space allotted for the run of the stairs.

There is a certain proportion existing between th tread and riser of a stair, that should be kept to as clos as possible when laying out the work Architect

say that the exact measurement for a tread and riser should be sixteen inches, or thereabouts. That is, if a riser is made six inches, the tread should be ten inches wide, and so on. I give a table herewith, showing the rule generally made use of by stair builders for determining the widths of risers and treads:

Treads Inches	*Risers* Inches	*Treads* Inches	*Risers* Inches
5	9	12	5½
6	8½	13	5
7	8	14	4½
8	7½	15	4
9	7	16	3½
10	6½	17	3
11	6	18	2½

It is seldom, however that the proportion of the

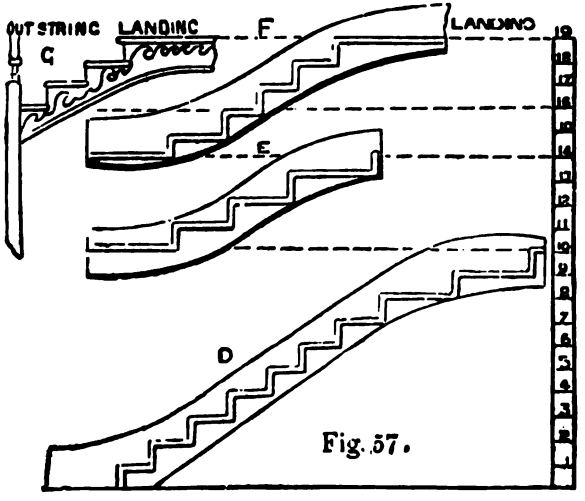


Fig. 57.

riser and step is exactly a matter of choice—the room

allotted to the stairs usually determines this proportion; but the above will be found a useful standard, to which it is desirable to approximate.

In better class buildings the number of steps is considered in the plan, which it is the business of the architect to arrange, and in such cases the height of the story-rod is simply divided to the number required.

An elevation of a stair with winders is shown at Fig. 57, where the story-rod is in evidence with the number of risers figured off.

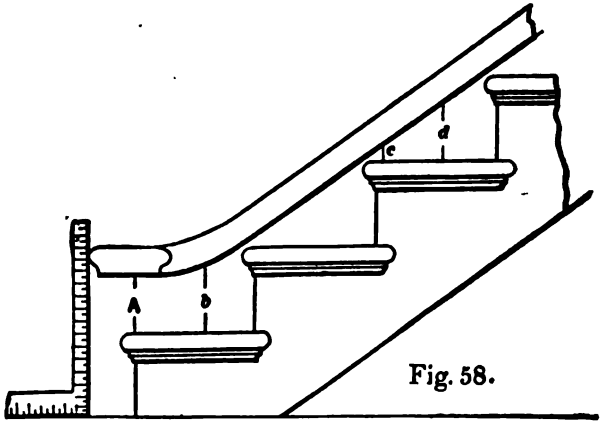


Fig. 58.

Fig. 58 shows a portion of an open string stair, with a part of the rail laid on it at AB, CD, and the newel cap with the projection at A. This shows how the cap should stand over the lower step.

Fig. 59 shows the manner of constructing the step: S represents the string, R the risers, T the tread, O the nosing and cove moulding, and B is a block glued or otherwise fastened to both riser and tread to render

them strong and firm. It will be seen the riser is let into the tread, and has a shoulder on the inside. The bottom of the riser is nailed to the back of the next lower tread, which binds the whole lower part together. The nosing of the stair is generally returned at the open end of the tread, and this covers the end wood of the tread and the joints of the balusters, as shown at Fig 60.

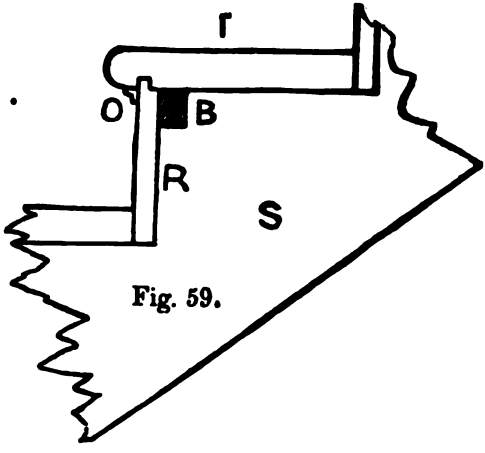


Fig. 59.

When a stair is bracketed, as shown at B, Fig. 60, the point of the riser on its string end should be left standing past the string the thickness of the bracket, and the end of the bracket miters against it, thus avoiding the necessity of showing end wood or joint The cove should finish inside the length of the bracket, and the nosing should finish just outside the length of the bracket. When brackets are employed

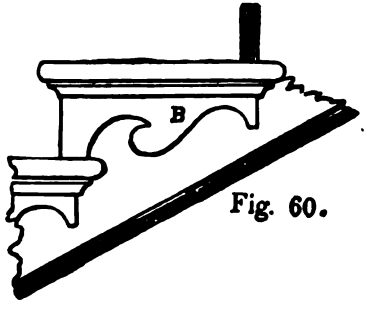


Fig. 60.

they should continue along the cylinder and all around the well-hole trimmers, though they may be varied to suit conditions when continuously running on a straight horizontal facia.

CHAPTER III

JOINER'S WORK—USEFUL MISCELLANEOUS EXAMPLES

I am well aware that workmen are always on the lookout for details of work, and welcome everything in this line that is new. While styles and shapes change from year to year, like fashion in women's dress, the principles of construction never change, and styles of finish in woodwork that may be in vogue to-day, may be old-fashioned and discarded next year, therefore it may not be wise to load these pages with many examples of finish as made use of to-day. A few examples, however, may not be out of place, so I close this section by offering a few pages of such details as I feel assured will be found useful for a long time to come.

Fig. 1 is a full page illustration of three examples of stairs and newels in modern styles. The upper one is a colonial stairway with a square newel, as shown at A. A baluster is also shown, so that the whole may be copied if required. The second example shows two newels and balusters, and paneled string and spandril AB, also section of paneled work on end of short flight. The third shows a plain open stair, with baluster and newel, the latter starting from first step.

At Fig. 2, which is also a full page, seven of the latest designs for doors are shown. Those marked

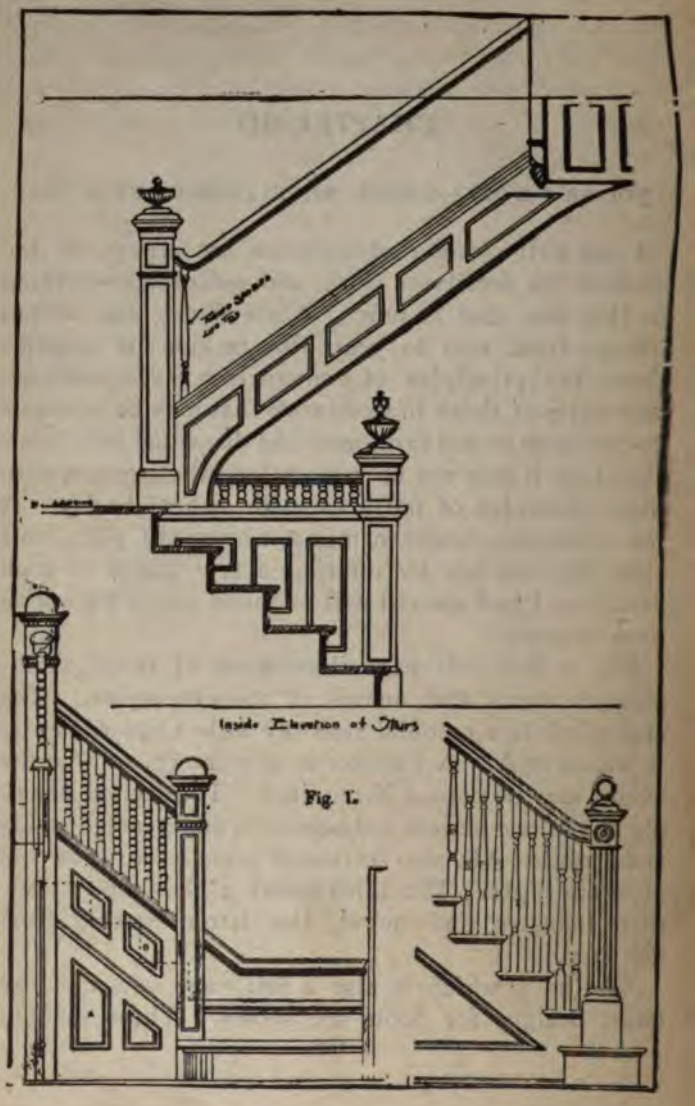
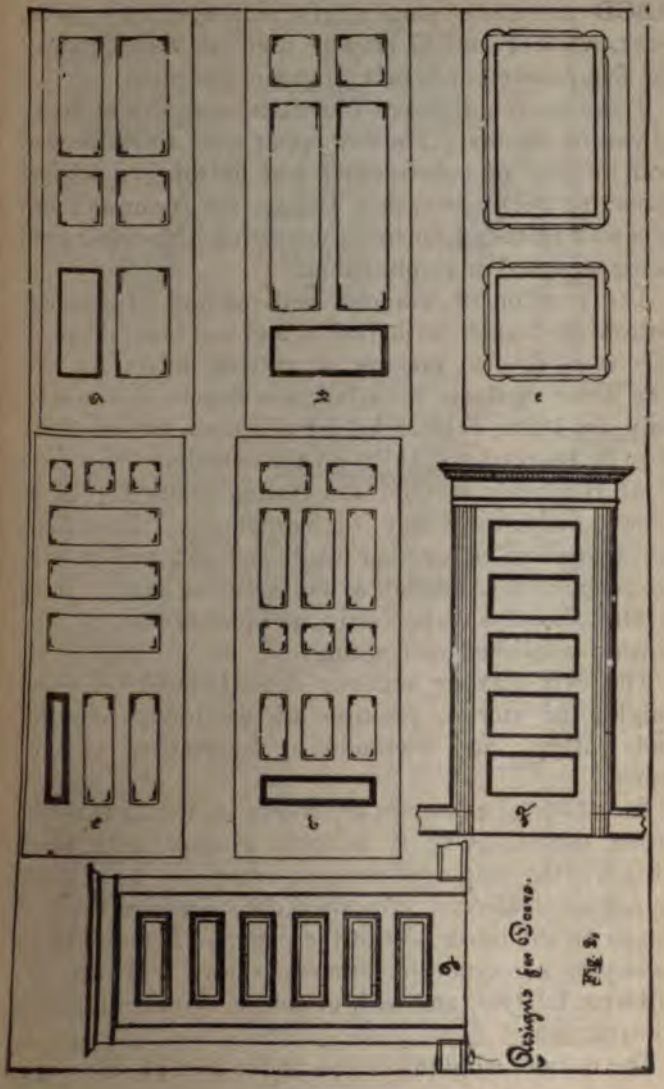


Fig. 1.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Designs for Doors.
Fig 4.

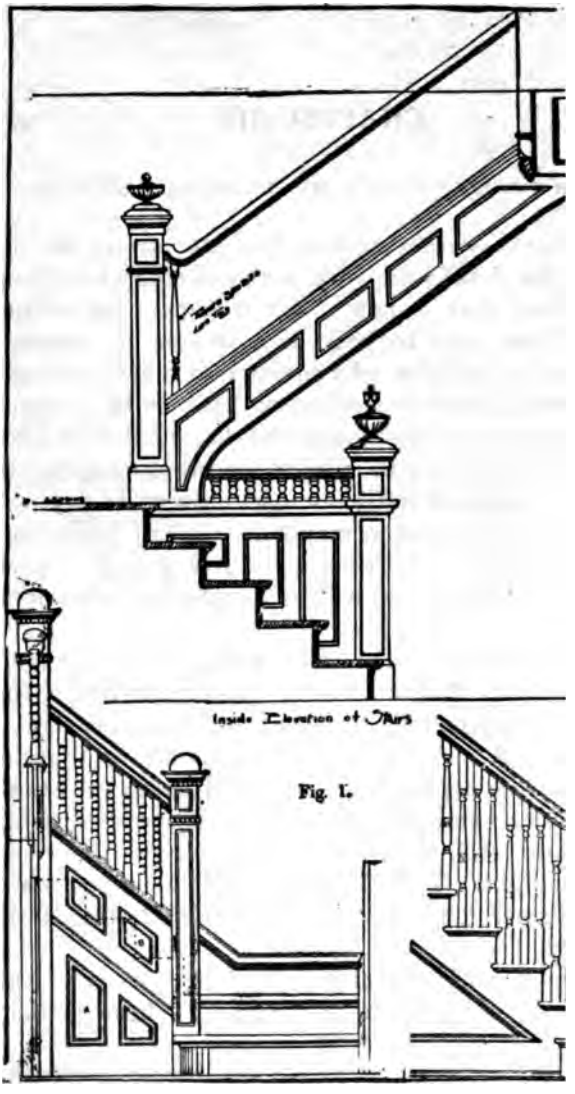
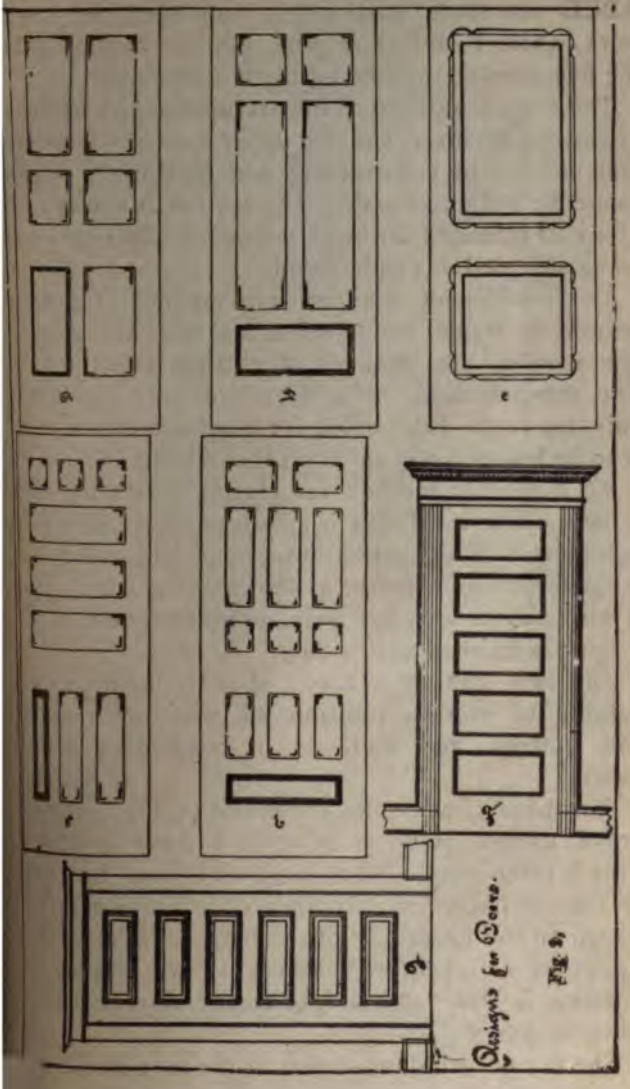


Fig. I.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Designs for Doors.
Fig. 2.

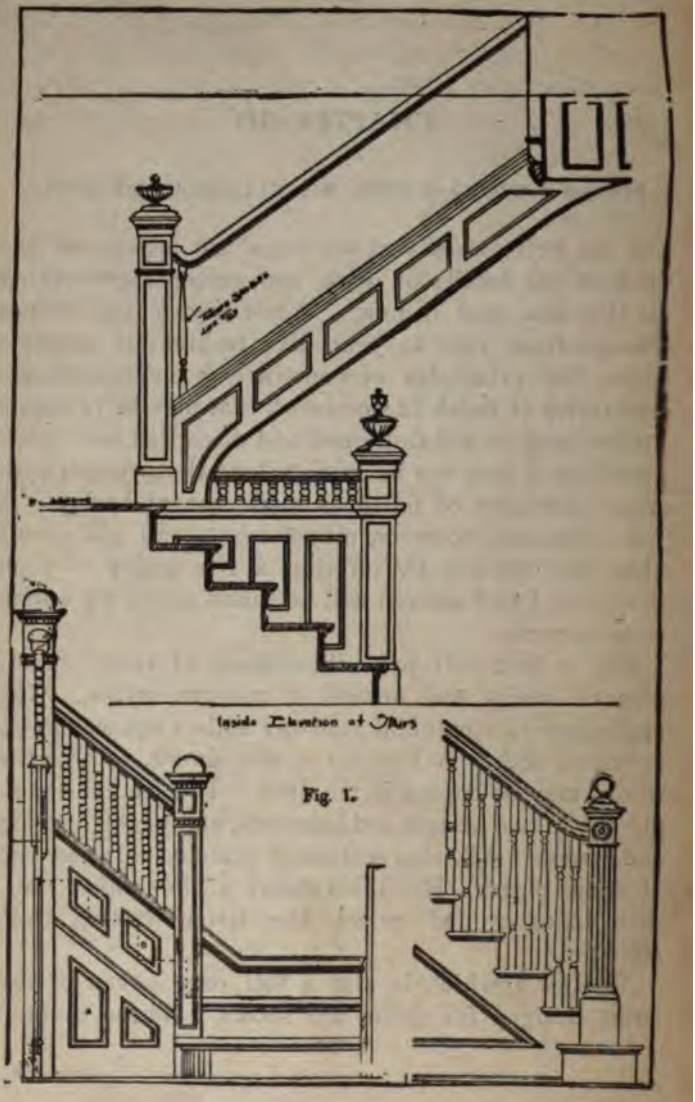
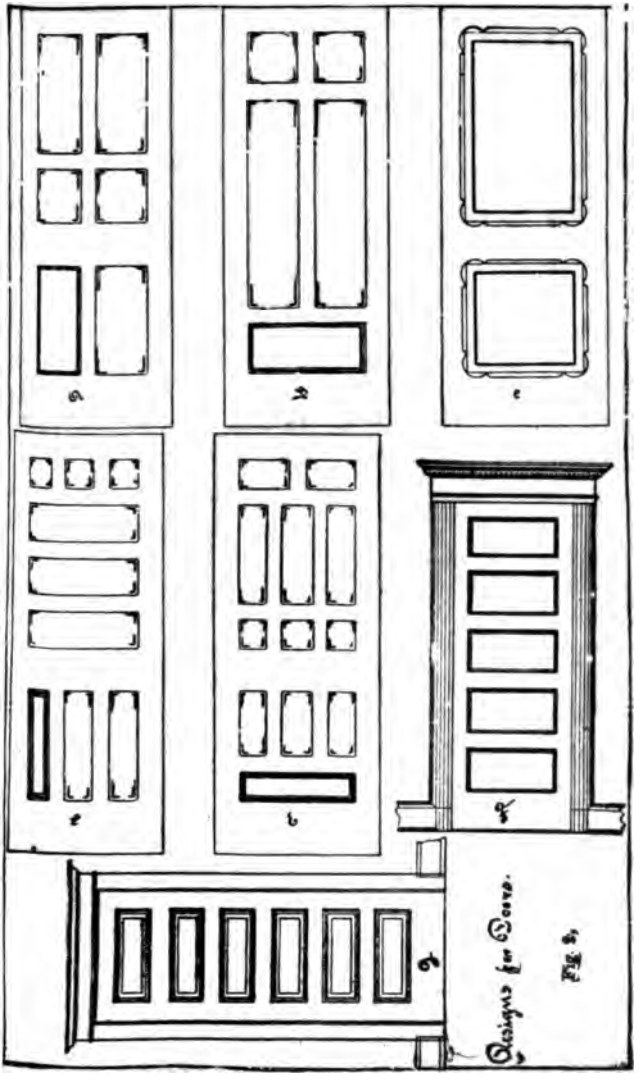


Fig. 1.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Designs for Doors.
Fig. 9.

ABCD are more particularly employed for inside work, while F and G may be used on outside work; the five-paneled door being the more popular.

There are ten different illustrations, shown at Fig. 3, of various details. The five upper ones show the general method of constructing and finishing a window frame for weighted sash. The section A shows a part of a wall intended for brick veneering, the upper story being shingled or clapboarded.

The position of windows and method of finishing bottom of frame, both inside and out, are shown in this section, also manner of cutting joists for sill. The same method—on a larger scale—is shown at C, only the latter is intended for a balloon frame, which is to be boarded and sided on the outside.

At B another method for cutting joists for sill is shown, where the frame is a balloon one. This frame is supposed to be boarded inside and out, and grounds are planted on for finish, as shown at the base. There is also shown a carpet strip, or quarter-round. The outside is finished with siding.

The two smaller sections show foundation walls, heights of stories, position of windows, cornices and gutters, and methods of connecting sills to joists.

A number of examples are shown in Fig. 4 that will prove useful. One is an oval window with keys. This is often employed to light vestibules, back stairs or narrow hallways. Another one, without keys, is shown on the lower part of the page. There are three examples of eyebrow dormers shown. These are different in style, and will, of course, require different construction.

The dormer window, shown at the foot of the page,

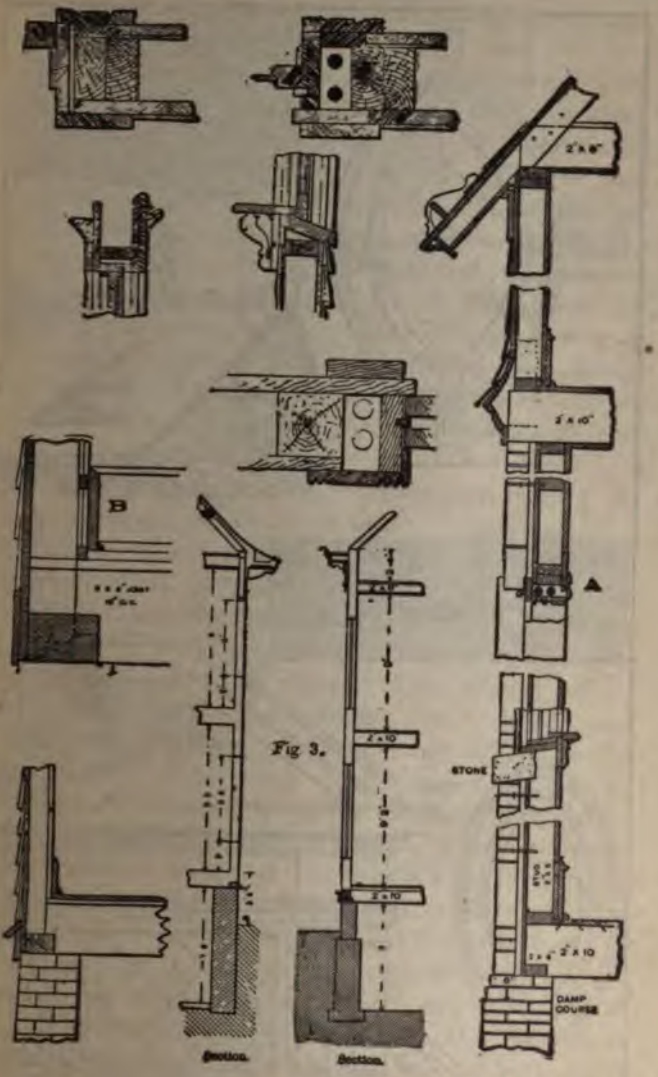


Fig 3.

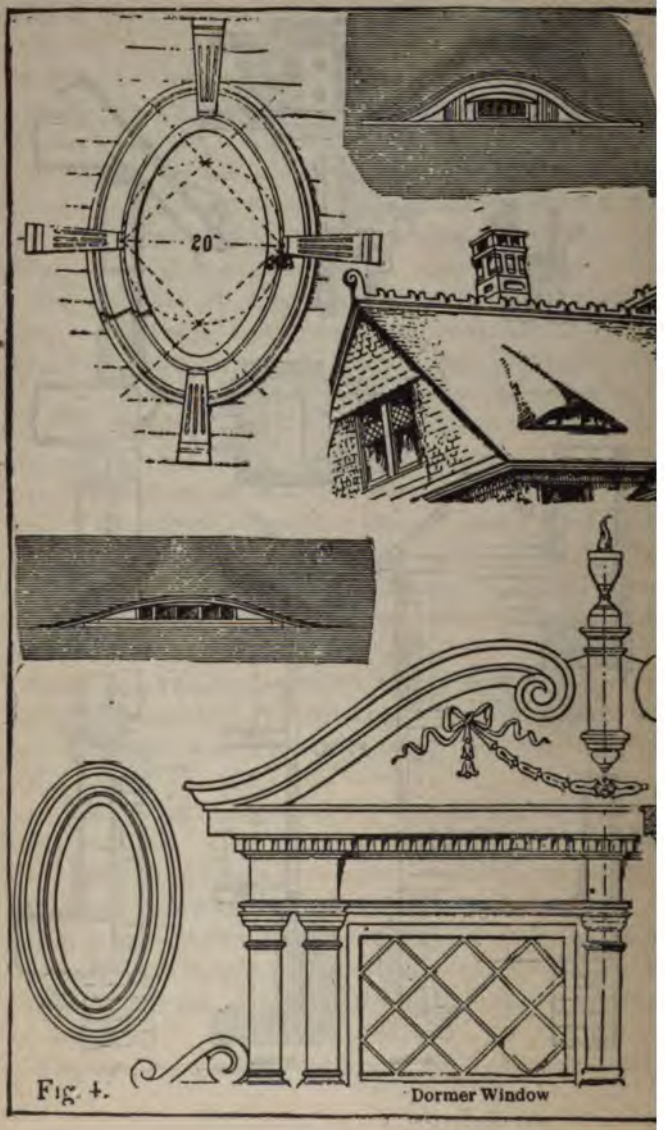


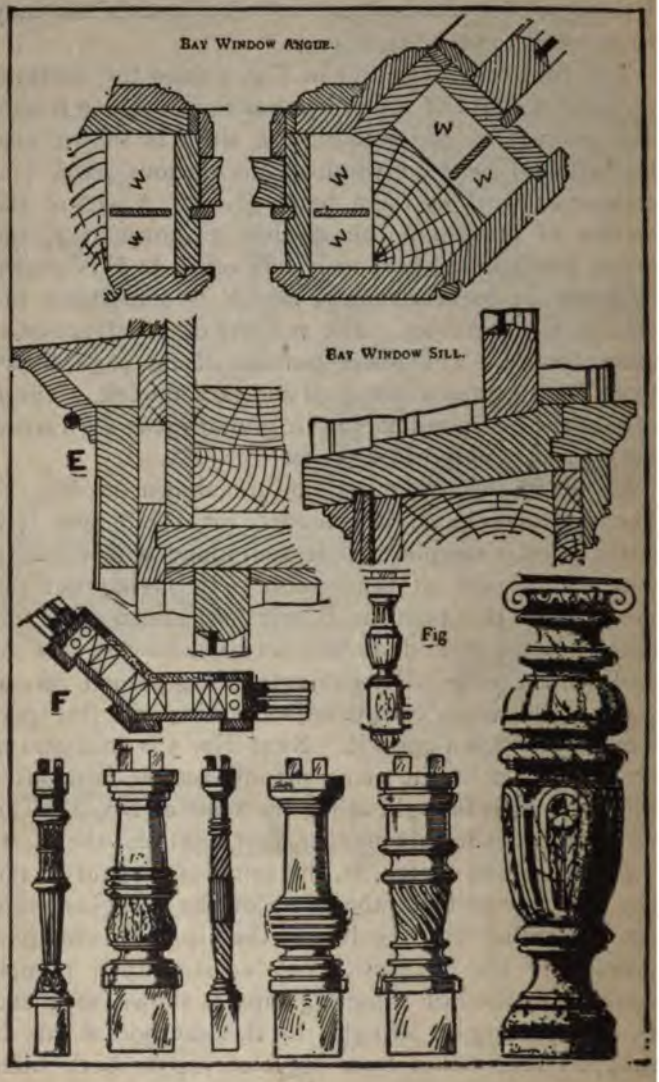
Fig. 4. Dormer Window

is designed for a house built in colonial style, but may be adapted to other styles.

The four first examples in Fig. 5 show the sections of various parts of a bay window for a balloon frame. The manner of constructing the angle is shown, also the sill and head of window, the various parts and manner of working them being given. A part of the section of the top of the window is shown at E, the inside finish being purposely left off. At F is shown an angle of greater length, which is sometimes the case in bay windows. The manner of construction is quite simple. The lower portion of the page shows some fine examples of turned and carved work. These will often be found useful in giving ideas for turned work for a variety of purposes.

Six examples of shingling are shown in Fig. 6. The first sketch, A, is intended for a hip, and is a fairly good example, and if well done will insure a water-tight roof at that point. In laying out the shingles for this plan the courses are managed as follows: No. 1 is laid all the way out to the line of the hip, the edge of the shingle being planed off, so that course No. 2, on the adjacent side will line perfectly tight down upon it. Next No. 3 is laid and is dressed down in the same manner as the first, after which No. 4 is brought along the same as No. 2. The work proceeds in this manner, first right and then left.

In the second sketch, B, the shingles are laid on the hip in a way to bring the grain of the shingles more nearly parallel with the line of the hip. This method overcomes the projection of cross-grained points. Another method of shingling hips is shown at C and D. In putting on shingles by this method a line is snapped four inches from angle of hip on both sides


Bay Window Angle.
W
W
W
W
W
W
Bay Window Sill.
E
F
Fig

of the ridge, as indicated by the dotted lines in C, then bring the corner of the shingles of each course to the line as shown. When all through with the plain shingling, make a pattern to suit, and only cut the top to shape, as the bottoms or butts will break joints every time, and the hip line will lay square with the hip line, as shown at D; thus making a first-class water-tight job, and one on which the shingles will not curl up, and it will have a good appearance as well.

At E a method is shown for shingling a valley, where no tin or metal is employed. The manner of doing this work is as follows: First take a strip 4 inches wide and chamfer it on the edges on the outside, so that it will lay down smooth to the sheeting, and nail it into the valley. Take a shingle about 4 inches wide to start with and lay lengthwise of the valley, fitting the shingle on each side. The first course, which is always double, would then start with the narrow shingle, marked B, and carried up the valley, as shown in the sketch. Half way between each course lay a shingle, A, about 4 or 5 inches wide, as the case requires, chamfering underneath on each side, so that the next course will lie smooth over it.

If tin or zinc can be obtained, it is better it should be laid in the valley, whether this method be adopted or not.

The sketch shown at F is intended to illustrate the manner in which a valley should be laid with tin, zinc or galvanized iron. The dotted lines show the width of the metal, which should never be less than fourteen inches to insure a tight roof. The shingles should lap over as shown, and not less than four inches of the valley, H, should be clear of shingles

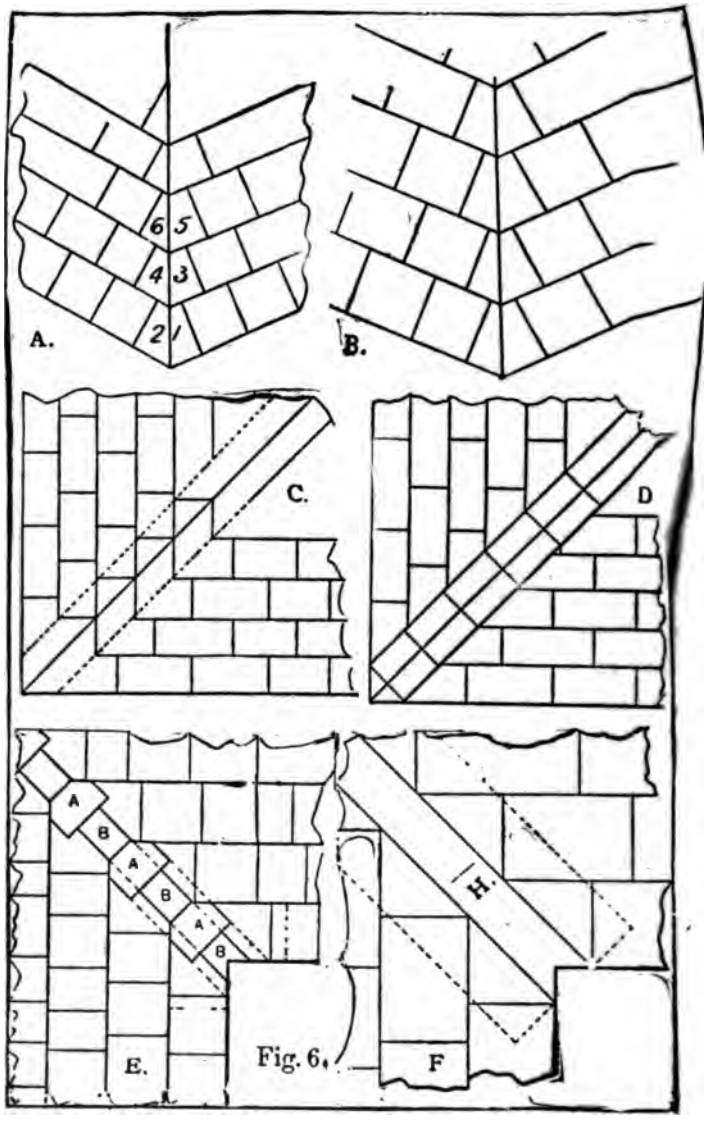


Fig. 6.

in order to insure plenty of space for the water to flow during a heavy rain storm. A great deal of care should be taken in shingling and finishing a valley, as it is always a weak spot in the roof.

PART IV

USEFUL TABLES AND MEMORANDA FOR BUILDERS

Table showing quantity of material in every four lineal feet of exterior wall in a balloon frame building, height of wall being given:

Length of Studs.	Size of Sills.	Size of Studs, Braces, etc.	Quantity of Rough Lumber	Quantity of Inch Boarding.	Siding in sup. feet.	Tar Paper in sup. feet.
8	6x 6	2x4 studs.	42	36	40	74
10	6x 8	4x4 braces.	52	44	50	80
12	6x10	4x4 plates.	62	53	60	96
14	6x10	1x6 ribbons.	69	62	70	112
16	8x10		82	71	80	128
18	8x10	studs.	87	80	90	144
20	8x12	16 inches from	98	88	100	160
22	9x12	centers.	109	97	110	176
24	10x12		119	106	120	192
18	10x10	2x6 studs.	122	80	90	144
20	10x12	6x6 braces.	137	88	100	160
22	10x12	4x6 plates.	145	97	110	176
24	12x12	1x6 ribbons.	162	106	120	192
26	10x14		169	114	130	208
28	10x14	studs 16 inch centers.	176	123	140	224
30	12x14		198	132	150	240

Table showing amount of lumber in rafters, collar-piece and boarding, and number of shingles to four lineal feet of roof, measured from eave to eave over ridge. Rafters 16-inch centers:

Width of House, Feet.	Size of Rafters.	Size of Collar-piece.	Quantity of Lumber in Rafter and Collar-piece.	Quantity of Boarding, Feet.	No. of Shingles.
14	2x4	2x4	39	61	560
16	2x4	2x4	45	70	640
18	2x4	2x4	50	79	720
20	2x4	2x4	56	88	800
22	2x4	2x4	62	97	880
24	2x4	2x4	67	106	960
20	2x6	2x6	84	88	800
22	2x6	2x6	92	97	880
24	2x6	2x6	101	106	960
26	2x6	2x6	109	115	1040
28	2x6	2x6	117	124	1120
30	2x6	2x6	126	133	1200

A proper allowance for waste is included in the above. Roof, one-fourth pitch.

Table showing the requisite sizes of girders and joists for warehouses, the span and distances apart being given:

Distance apart.	Span of Girders.				Joists.	Remarks.
	6 Feet.	8 Feet.	10 Feet.	12 Feet.		
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	
10	8x12	12x13	12x16	14x18	2½x10	Girders to have a bearing at each end and joists 6 in.
12	9x12	12x14	12x18	16x18	3 x10	
14	10x12	12x15	14x18	.....	3 x12	

Table as before, adapted for churches, public halls, etc.

Distance Apart.	Span of Girders.				Joists.	Remarks.
	6 Feet.	8 Feet.	10 Feet.	12 Feet.		
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	
12	6x10	8x12	12x14	12x16	2 x 8	
13	9x11	9x12	11x15	12x17	2 x 9	Bearings of
14	6x12	10x12	12x15	11x18	2 x 9	girders and
15	7x12	11x12	11x16	12x16	2 x 10	joists as
16	8x12	12x12	12x16	13x18	2 x 10	above.
17	8x12	9x14	12x17	14x18	2 x 12	
18	9x12	10x14	11x18	.....	2 x 12	
19	9x12	11x14	12x18	.....	2½ x 12	Both tables
20	10x12	12x14	13x18	.....	2½ x 12	are calcu-
21	10x12	11x15	14x18	.....	2½ x 12	lated for yel-
22	11x12	12x15	.....	.....	3 x 12	low pine.
23	11x12	11x16	.....	.....	3 x 12	
24	10x13	12x16	.....	.....	3 x 13	
25	10x13	12x17	.....	.....	3 x 13	
26	10x14	12x18	.....	.....	3 x 14	
27	10x14	12x18	.....	.....	3 x 14	

Table showing quantity of lumber in every four lineal feet of partition, studs being placed 16 centers, waste included:

Height of Partition, Feet.	Quantity of Studs 2x4 Feet.	If 2x6 Feet.
8	20	30
9	23	34
10	26	38
11	29	42
12	32	46
13	35	51
14	38	55
15	41	59
16	44	64

Lumber Measurement Table

Length.	2x4	Length.	2x6	Length.	2x8	Length.	2x10	Length.	3x6	Length.	3x8
12	8	12	12	12	16	12	20	12	18	12	24
14	9	14	14	14	19	14	23	14	21	14	28
16	11	16	16	16	21	16	27	16	24	16	32
18	12	18	18	18	24	18	30	18	27	18	36
20	13	20	20	20	27	20	33	20	30	20	40
22	15	22	22	22	29	22	37	22	33	22	44
24	16	24	24	24	32	24	40	24	36	24	48
26	17	26	26	26	35	26	43	26	39	26	52
	3x10		3x12		4x4		4x6		4x8		6x6
12	30	12	36	12	16	12	24	12	32	12	36
14	35	14	42	14	19	14	28	14	37	14	42
16	40	16	48	16	21	16	32	16	43	16	48
18	45	18	54	18	24	18	36	18	48	18	54
20	50	20	60	20	27	20	40	20	53	20	60
22	55	22	66	22	29	22	44	22	59	22	66
24	60	24	72	24	32	24	48	24	64	24	72
26	65	26	78	26	35	26	52	26	69	26	78
	6x8		8x8		8x10		10x10		10x12		12x12
12	48	12	64	12	80	12	100	12	120	12	144
14	56	14	75	14	93	14	117	14	140	14	168
16	64	16	85	16	107	16	133	16	160	16	192
18	72	18	96	18	120	18	150	18	180	18	216
20	80	20	107	20	133	20	167	20	200	20	240
22	88	22	117	22	147	22	183	22	220	22	264
24	96	24	128	24	160	24	200	24	240	24	288
26	104	26	139	26	173	26	217	26	260	26	312

Strength of Materials

Resistance to extension and compression, in pounds per square inch section of some materials.

Name of the Material.	Resistance to Extension.	Resistance to Compression	Tensile Stre th in Practice.	Comp. Strength in Practice.
White pine...	10,000	6,000	2,000	1,200
White oak....	15,000	7,500	3,000	1,500
Rock elm.....	16,000	8,011	3,200	1,602
Wroughtiron	60,000	50,000	12,000	10,000
Cast iron.....	20,000	100,000	4,000	20,000

In practice, from one-fifth to one-sixth of the strength is all that should be depended upon

Table of Superficial or Flat Measure

By which the contents in *Superficial Feet*, of Boards, Plank, Paving, etc., of any *Length* and *Breadth*, can be obtained, by multiplying the decimal expressed in the table by the length of the board, etc.

Breadth Inches.	Area of a lineal foot.	Breadth Inches.	Area of a lineal foot.	Breadth Inches.	Area of a lineal foot.	Breadth Inches.	Area of a lineal foot.
1/4	.0208	3 1/4	.2708	6 1/4	.5208	9 1/4	.7708
1/3	.0417	3 1/3	.2916	6 1/3	.5416	9 1/3	.7917
3/8	.0625	3 3/8	.3125	6 3/8	.5625	9 3/8	.8125
1	.0834	4	.3334	7	.5833	10	.8334
1 1/4	.1042	4 1/4	.3542	7 1/4	.6042	10 1/4	.8542
1 1/3	.125	4 1/3	.375	7 1/3	.625	10 1/3	.875
1 3/8	.1459	4 3/8	.3958	7 3/8	.6458	10 3/8	.8959
2	.1667	5	.4167	8	.6667	11	.9167
2 1/4	.1875	5 1/4	.4375	8 1/4	.6875	11 1/4	.9375
2 1/3	.2084	5 1/3	.4583	8 1/3	.7084	11 1/3	.9583
2 3/8	.2292	5 3/8	.4792	8 3/8	.7292	11 3/8	.9792
3	.25	6	.5	9	.75	12	1.0000

Round and Equal-Sided Timber Measure

Table for ascertaining the number of Cubical Feet, or solid contents, in a Stick of Round or Equal-Sided Timber, Tree, etc.

¼ girt in in.	Area in feet.	¼ girt in in.	Area in feet.	¼ girt in in.	Area in feet.	¼ girt in in.	Area in feet.	¼ girt in in.	Area in feet.
6	.25	10 3/4	.803	15 1/4	1.668	20 1/4	2.898	25	4.34
6 1/3	.272	11	.84	15 3/4	1.722	20 1/3	2.917	25 1/3	4.428
6 1/3	.294	11 1/3	.878	16	1.777	20 3/4	2.99	25 1/3	4.516
6 3/4	.317	11 1/3	.918	16 1/3	1.833	21	3.062	25 3/4	4.605
7	.34	11 3/4	.959	16 1/3	1.89	21 1/3	3.136	26	4.694
7 1/3	.364	12	1.	16 3/4	1.948	21 1/3	3.209	26 1/3	4.785
7 1/3	.39	12 1/3	1.042	17	2.006	21 3/4	3 285	26 1/3	4.876
7 3/4	.417	12 1/3	1.085	17 1/3	2.066	22	3.362	26 3/4	4.969
8	.444	12 3/4	1.129	17 1/3	2.126	22 1/3	3.438	27	5.062
8 1/3	.472	13	1.174	17 3/4	2.187	22 1/3	3.516	27 1/3	5.158
8 1/3	.501	13 1/3	1.219	18	2.25	22 3/4	3.598	27 1/3	5.252
8 3/4	.531	13 1/3	1.265	18 1/3	2.313	23	3.673	27 3/4	5.348
9	.562	13 3/4	1.313	18 1/3	2.376	23 1/3	3.754	28	5.444
9 1/3	.594	14	1.361	18 3/4	2.442	23 1/3	3.835	28 1/3	5.542
9 1/3	.626	14 1/3	1.41	19	2.506	23 3/4	3.917	28 1/3	5.64
9 3/4	.659	14 1/3	1.46	19 1/3	2.574	24	4.	28 3/4	5.74
10	.694	14 3/4	1.511	19 1/3	2.64	24 1/3	4.084	29	5.84
10 1/3	.73	15	1.562	19 3/4	2.709	24 1/3	4.168	29 1/3	5.941
10 1/3	.766	15 1/3	1.615	20	2.777	24 3/4	4.254	29 1/3	6.044

Shingling

To find the number of shingles required to cover 100 square feet deduct 3 inches from the length, divide the remainder by 3, the result will be the exposed length of a shingle; multiplying this with the average width of a shingle, the product will be the exposed area. Dividing 14,400, the number of square inches in a square, by the exposed area of a shingle will give the number required to cover 100 square feet of roof.

In estimating the number of shingles required, an allowance should always be made for waste.

Estimates on cost of shingle roofs are usually given per 1,000 shingles.

Table for Estimating Shingles

Length of Shingles.	Exposure to Weather, Inches.	No. of Sq. Ft. of Roof Covered by 1000 Shingles.		No. of Shingles Required for 100 Sq. Ft. of Roof.	
		4 In. Wide.	6 In. Wide.	4 In. Wide.	6 In. Wide.
15 in.	4	111	167	900	600
18	5	139	208	720	480
21	6	167	250	600	400
24	7	194	291	514	343
27	8	222	333	450	300

Siding, Flooring, and Laths

One-fifth more siding and flooring is needed than the number of square feet of surface to be covered, because of the lap in the siding matching.

1,000 laths will cover 70 yards of surface, and 11 pounds of lath nails will nail them on. Eight bushels of good lime, 16 bushels of sand, and 1 bushel of hair, will make enough good mortar to plaster 100 square yards.

Excavations

Excavations are measured by the yard (27 cubic feet) and irregular depths or surfaces are generally averaged in practice.

Number of Nails Required in Carpentry Work

To case and hang one door, 1 pound.
To case and hang one window, ¾ pound.
Base, 100 lineal feet, 1 pound.
To put on rafters, joists, etc., 3 pounds to 1,000 feet.
To put up studding, same.
To lay a 6-inch pine floor, 15 pounds to 1,000 feet.

Sizes of Boxes for Different Measures

A box 24 inches long by 16 inches wide, and 28 inches deep will contain a barrel, or 3 bushels.

A box 24 inches long by 16 inches wide, and 14 inches deep will contain half a barrel.

A box 16 inches square and 8½ inches deep, will contain 1 bushel.

A box 16 inches by 8½ inches wide and 8 inches deep, will contain half a bushel.

A box 8 inches by 8½ inches square and 8 inches deep, will contain 1 peck.

A box 8 inches by 8 inches square and 4½ inches deep, will contain 1 gallon.

A box 8 inches by 4 inches square and 4½ inches deep, will contain half a gallon.

A box 4 inches by 4 inches square and 4½ inches deep, will contain 1 quart.

A box 4 feet long, 3 feet 5 inches wide, and 2 feet 8 inches deep, will contain 1 ton of coal.

Masonry

Stone masonry is measured by two systems, quarryman's and mason's measurements.

By the quarryman's measurements the actual contents are measured—that is, all openings are taken out and all corners are measured single.

By the mason's measurements, corners and piers are doubled, and no allowance made for openings less than 3′ 0″x5′ 0″ and only half the amount of openings larger than 3′ 0″x5′ 0″.

Range work and cut work is measured superficially and in addition to wall measurement.

An average of six bushels of sand and cement per perch of rubble masonry.

Stone walls are measured by the perch (24¾ cubic feet, or by the cord of 128 feet). Openings less than 3 feet wide are counted solid; over 3 feet deducted, but 18 inches are added to the running measure for each jamb built.

Arches are counted solid from their spring. Corners of buildings are measured twice. Pillars less than 3 feet are counted on 3 sides as lineal, multiplied by fourth side and depth.

It is customary to measure all foundation and dimension stone by the cubic foot. Water tables and base courses by lineal feet. All sills and lintels or ashlar by superficial feet, and no wall less than 18 inches thick.

The height of brick or stone piers should not exceed 12 times their thickness at the base.

Masonry is usually measured by the perch (containing 24.75 cubic feet), but in practice 25 cubic feet are considered a perch of masonry.

Concreting is usually measured by the cubic yard (27 cubic feet).

A cord of stone, 3 bushels of lime and a cubic yard of sand, will lay 100 cubic feet of wall.

Cement, 1 bushel, and sand, 2 bushels, will cover 3½ square yards 1 inch thick, 4½ square yards ¾ inch thick, and 6¾ square yards ½ inch thick; 1 bushel of cement and 1 of sand will cover 2¼ square yards 1 inch thick, 3 square yards ¾ inch thick and 4½ square yards ½ inch thick.

Brick Work

Brick work is generally measured by 1,000 bricks laid in the wall. In consequence of variations in size of bricks, no rule for volume of laid brick can be exact. The following scale is, however, a fair average:

7	com.	bricks	to a	super.	ft.	4	in.	wall.
14	"	"	"	"	"	9	"	"
21	"	"	"	"	"	13	"	"
28	"	"	"	"	"	18	"	"
35	"	"	"	"	"	22	"	"

Corners are not measured twice, as in stone work. Openings over 2 feet square are deducted. Arches are counted from the spring. Fancy work counted 1½ bricks for 1. Pillars are measured on their face only.

A cubic yard of mortar requires 1 cubic yard of sand and 9 bushels of lime, and will fill 30 hods.

One thousand bricks closely stacked occupy about 56 cubic feet.

One thousand old bricks, cleaned and loosely stacked, occupy about 72 cubic feet.

One superficial foot of gauged arches requires 10 bricks.

Pavements, according to size of bricks, take 38 brick on flat and 60 brick on edge per square yard, on an average.

Five courses of brick will lay 1 foot in height on a chimney, 6 bricks in a course will make a flue 4 inches wide and 12 inches long, and 8 bricks in a course will make a flue 8 inches wide and 16 inches long.

Slating

A square of slate or slating is 100 superficial feet.

In measuring, the width of eaves is allowed at the widest part. Hips, valleys and cuttings are to be measured lineal, and 6 inches extra is allowed.

The thickness of slates required is from $\frac{3}{16}$ to $\frac{5}{16}$ of an inch, and their weight varies when lapped from 4 to 6¾ pounds per square foot.

The "laps" of slates vary from 2 to 4 inches, the standard assumed to be 3 inches.

To Compute the Number of Slates of a Given Size Required per Square

Subtract 3 inches from the length of the slate, multiply the remainder by the width and divide by 2. Divide 14,400 by the number so found and the result will be the number of slates required.

Table showing number of slates and pounds of nails required to cover 100 square feet of roof.

Sizes of Slate	Length of Exposure.	No. Required.	Nails Required.
14 in. x 28 in.	12½ in.	83	.6 lbs.
12 x 24	10½	114	.833
11 x 22	9½	138	1.
10 x 20	8½	165	1.33
9 x 18	7½	214	1.5
8 x 16	6½	277	2.
7 x 14	5½	377	2.66
6 x 12	4½	533	3.8

Approximate Weight of Materials for Roofs

Material.	Average Weight, Lb. per Sq. Ft.
Corrugated galvanized iron, No. 20, unboarded	2¼
Copper, 16 oz. standing seam	1¼
Felt and asphalt, without sheathing	2
Glass, ⅛ in. thick	1¾
Hemlock sheathing, 1 in. thick	2
Lead, about ⅛ in. thick	6 to 8
Lath-and-plaster ceiling (ordinary)	6 to 8
Mackite, 1 in. thick, with plaster	10
Neponset roofing felt, 2 layers	⅛
Spruce sheathing, 1 in. thick	2½
Slate, $\frac{3}{16}$ in. thick, 3 in. double lap	6¾
Slate, ⅛ in. thick, 3 in. double lap	4½
Shingles, 6 in. x 18 in., ⅜ to weather	2
Skylight of glass, $\frac{3}{16}$ to ½ in., including frame	4 to 10
Slag roof, 4-ply	4
Terne Plate, IC, without sheathing	½
Terne Plate, IX, without sheathing	⅝
Tiles (plain), 10⅛ in. x 6¼ x ⅝ in.—5¼ in. to weather	18
Tiles (Spanish) 14½ in. x 10⅛ in.—7¼ in. to weather	8½
White-pine sheathing, 1 in. thick	2½
Yellow-pine sheathing, 1 in. thick	4

Snow and Wind Loads

Data in regard to snow and wind loads are necessary in connection with the design of roof trusses.

Snow Load.—When the slope of a roof is over 12 inches rise per foot of horizontal run, a snow and accidental load of 8 pounds per square foot is ample. When the slope is under 12 inches rise per foot of run, a snow and accidental load of 12 pounds per square foot should be used. The snow load acts vertically, and therefore should be added to the dead load in designing roof trusses. The snow load may be neglected when a high wind pressure has been considered, as a great wind storm would very likely remove all the snow from the roof.

Wind Load.—The wind is considered as blowing i a horizontal direction, but the resulting pressure upo the roof is always taken normal (at right angles) t the slope. The wind pressure against a vertical plan depends on the velocity of the wind, and, as asce tained by the United States Signal Service at Mour Washington, N. H., is as follows:

Velocity. (Mi. per Hr.)	*Pressure.* (Lb. per Sq. Ft.)	
10	0.4	Fresh breeze.
20	1.6	Stiff breeze.
30	3.6	Strong wind.
40	6.4	High wind.
50	10.0	Storm.
60	14.4	Violent storm.
80	25.6	Hurricane.
100	40.0	Violent hurrican

The wind pressure upon a cylindrical surface is one half that upon a flat surface of the same height an width.

Since the wind is considered as traveling in a hori zontal direction, it is evident that the more nearly vertical the slope of the roof, the greater will be the pressure, and the more nearly horizontal the slope, the less will be the pressure. The following table gives the pressure exerted upon roofs of different slopes, by a wind pressure of 40 pounds per square foot on a vertical plane, which is equivalent in intensity to a violent hurricane.

UNITED STATES WEIGHTS AND MEASURES

Land Measure

1 sq. acre = 10 sq. chains = 100,000 sq. links = 6,272,640 sq. in
1 " " = 160 sq. rods = 4,840 sq. yds. = 43,560 sq. f

Note.—208.7103 feet square, or 69.5701 yards square, or 220 fee by 198 feet square=1 acre.

Cubic or Solid Measure

1 cubic yard = 27 cubic feet.
1 cubic foot = 1,728 cubic inches.
1 cubic foot = 2,200 cylindrical inches.
1 cubic foot = 3,300 spherical inches.
1 cubic foot = 6,600 conical inches.

Linear Measure

12 inches (in.) ..... = 1 foot ..... ft.
3 feet ..... = 1 yard ..... yd.
5.5 yards ..... = 1 rod ..... rd.
40 rods ..... = 1 furlong ..... fur.
8 furlongs ..... = 1 mile ..... mi.

in.	ft.	yd.	rd.	fur.	mi.
36 =	3 =	1			
198 =	16.5 =	5.5 =	1		
7,920 =	660 =	220 =	40 =	1	
63,360 =	5,280 =	1,760 =	320 =	8 =	1

Square Measure

144 square inches (sq. in.) = 1 square foot ..... sq. ft.
9 square feet ..... = 1 square yard ..... sq. yd.
30¼ square yards ..... = 1 square rod ..... sq. rd.
160 square rods ..... = 1 acre ..... A.
640 acres ..... = 1 square mile ..... sq. mi.

Sq. mi.	A.	Sq. rd.	Sq. yd.	Sq. ft.	Sq. in.
1 =	640 =	102,400 =	3,097,600 =	27,878,400 =	4,014,489,600

Miscellaneous Measures and Weights

1 perch of stone = 1 ft. × 1 ft. 6 in. × 16 ft. 6 in. = 24.75 ft. cubic.
1 cord of wood, clay, etc., = 4 ft. × 4 ft. × 8 ft. = 128 ft. cubic.
1 chaldron = 36 bushels or 57.25 ft. cubic.
1 cubic foot of sand, solid, weighs 112½ lbs.
1 cubic foot of sand, loose, weighs 95 lbs.
1 cubic foot of earth, loose, weighs 93¾ lbs.
1 cubic foot of common soil weighs 124 lbs.
1 cubic foot of strong soil weighs 127 lbs.
1 cubic foot of clay weighs 120 to 135 lbs.
1 cubic foot of clay and stone weighs 160 lbs.
1 cubic foot of common stone weighs 160 lbs.
1 cubic foot of brick weighs 95 to 120 lbs.
1 cubic foot of granite weighs 169 to 180 lbs.
1 cubic foot of marble weighs 166 to 170 lbs.
1 cubic yard of sand weighs 3,037 lbs.
1 cubic yard of common soil weighs 3,429 lbs.

Safe Bearing Loads

Brick and Stone Masonry.	Lb. per Sq. In.
Brick Work.	
Bricks, hard, laid in lime mortar	100
Hard, laid in Portland cement mortar	200
Hard, laid in Rosendale cement mortar	150
Masonry.	
Granite, capstone	700
Squared stonework	350
Sandstone, capstone	350
Squared stonework	175
Rubble stonework, laid in lime mortar	80
Rubble stonework, laid in cement mortar	150
Limestone, capstone	500
Squared stonework	250
Rubble, laid in lime mortar	80
Rubble, laid in cement mortar	150
Concrete, 1 Portland, 2 sand, 5 broken stone	150

Foundation Soils.	Tons per Sq. Ft.
Rock, hardest in native bed	100 —
Equal to best ashlar masonry	25-40
Equal to best brick	15-20
Clay, dry, in thick beds	4- 6
Moderately dry, in thick beds	2- 4
Soft	1- 2
Gravel and course sand, well cemented	8-10
Sand, compact and well cemented	4- 6
Clean, dry	2- 4
Quicksand, alluvial soil, etc.	.5- 1

Capacity of Cisterns for Each 10 Inches in Depth

Twenty-five feet in diameter holds	3059 gallo
Twenty feet in diameter holds	1958 gallo
Fifteen feet in diameter holds	1101 gallo
Fourteen feet in diameter holds	959 gallo
Thirteen feet in diameter holds	827 gallo
Twelve feet in diameter holds	705 gallo
Eleven feet in diameter holds	592 gallo
Ten feet in diameter holds	489 gallo
Nine feet in diameter holds	396 gallo
Eight feet in diameter holds	313 gallo
Seven feet in diameter holds	239 gallo
Six and one-half feet in diameter holds	206 gallo
Six feet in diameter holds	176 gallo
Five feet in diameter holds	122 gallo
Four and one-half feet in diameter holds	99 gallo

Four feet in diameter holds	78 gallons
Three feet in diameter holds	44 gallons
Two and one-half feet in diameter holds	30 gallons
Two feet in diameter holds	19 gallons

Number of Nails and Tacks per Pound

Name.	NAILS. Size.	No. per lb.
3 penny, fine	1⅛ inch	760 nails
3 "	1¼ "	480 "
4 "	1½ "	300 "
5 "	1¾ "	200 "
6 "	2⅛ "	160 "
7 "	2¼ "	128 "
8 "	2½ "	92 "
9 "	2¾ "	72 "
10 "	3 "	60 "
12 "	3¼ "	44 "
16 "	3½ "	32 "
20 "	4 "	24 "
30 "	4¼ "	18 "
40 "	5 "	14 "
50 "	5½ "	12 "
6 " fence	2 "	80 "
8 " "	2½ "	50 "
10 " "	3 "	34 "
12 " "	3¼ "	29 "

Name.	TACKS. Length.	No. per lb.
1 oz.	⅛ inch	16,000
1½ "	3-16 "	10,666
2 "	¼ "	8,000
2½ "	5-16 "	6,400
3 "	⅜ "	5,333
4 "	7-16 "	4,000
6 "	9-16 "	2,666
8 "	⅝ "	2,000
10 "	11-16 "	1,600
12 "	¾ "	1,333
14 "	13-16 "	1,143
16 "	⅞ "	1,000
18 "	15-16 "	888
20 "	1 "	800
22 "	1 1-16 "	727
24 "	1⅛ "	666

Wind Pressures on Roofs

(Pounds per Square Foot.)

Rise, Inches per Foot of Run.	Angle with Horizontal.	Pitch. Proportion of Rise to Span	Wind Pressure, Normal to Slope.
4	18° 25′	⅛	16.8
6	26° 33′	¼	23.7
8	33° 41′	⅜	29.1
12	45′′ 0′	½	36.1
16	53° 7′	⅝	38.7
18	56° 20′	¾	39.3
24	63° 27′	1	40.0

In addition to wind and snow loads upon roofs, the weight of the principals or roof trusses, including the other features of the construction, should be figured in the estimate. For light roofs, having a span of not over 50 feet, and not required to support any ceiling, the weight of the steel construction may be taken at 5 pounds per square foot; for greater spans, 1 pound per square foot should be added for each 10 feet increase in the span.

SUPPLEMENT TO

MODERN CARPENTRY AND JOINERY.

The aim in preparing this has been to supply necessary information for enabling a practical joiner to become a competent airtight-case maker, without the tedium of waiting, perhaps for years, until chance brings him into contact with one who has made a specialty of this class of work. I have endeavored, by means of illustrations, to elucidate as clearly as possible the points which are so frequently the cause of failure to those who, while having a good knowledge of wood-working, have not had the advantages of direct practical tuition in the intricacies of airtight-case making.

Before proceeding with the explanations, I would point out that the first and most important rule in joinery is to have the stuff planed up true, and gauged accurately to size.

I. AIRTIGHT WALL CASE WITH GLASS OR WOOD ENDS.

The general drawings of the airtight wall-case with glazed ends are given in Figs. 1 to 5 and the details in Figs. 6 to 9.

Framework. Figs. 6 and 7 give the width of the top and bottom rails for the front frame of the case, and, by adding the width of the top and bottom door-rails to each we determine the width of the rails required for the ends of the case, as shown in Fig. 5. The angle-stile must be ¼ inch more in thickness than the thick-

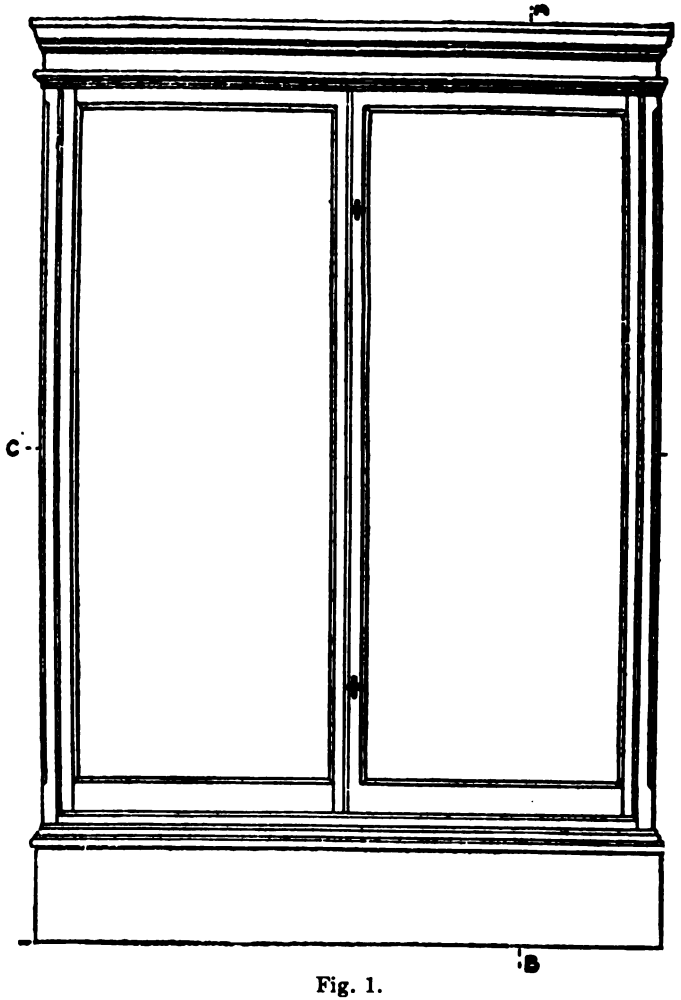


Fig. 1.

ness of the doors, in order to allow of a rebate bei formed to receive the glass at the ends of the case. (S M Fig. 8.)

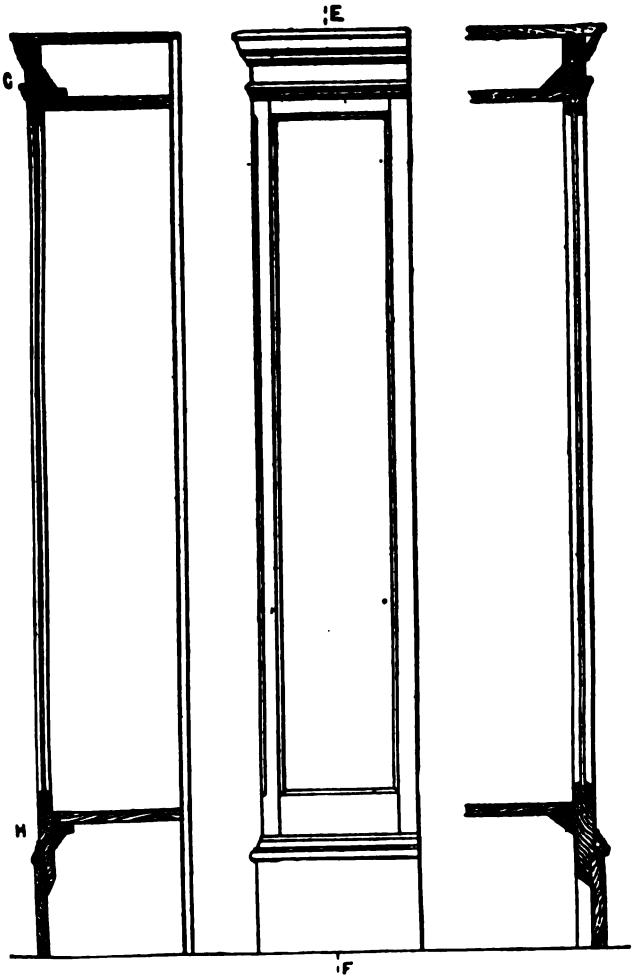


Fig. 2. Fig. 4. Fig. 5.

In setting out the framework (which is mortised and tenoned together in the ordinary way) the face shoulders of the front rails should be ⅛ inch longer than the

back shoulders. An eighth inch bead—for which the allowance has been made—is worked on the angle-stiles and bottom rail only, the edge of the top rail being left square. The moulding which is planted round the case, as shown in Fig. 6, serves to break the joint of the doors. The shoulders on the end rails are square with each other, the rebate being the same depth as the moulding.

Airtight joints. To make successfully the airtight joint between the angle-stile of the case and the hanging stile of the door (see Fig. 8) three planes are required. The first plane is used on the angle-stile for forming at the same time the two grooves, each 3/16 inch wide;

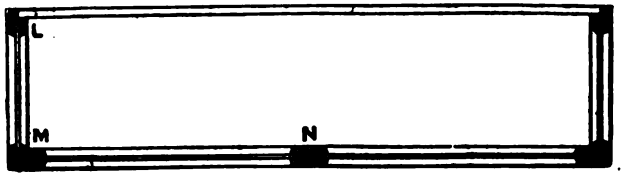


Fig. 3.

the second is used for working the two fillets together and the third for working the two hollows in the door stiles.

The front part of the frame must now be fitted together and the joints at the back of the frame cleared off, to allow the airtight planes to be worked from the back of the frame, that is, from the inside of the case, as the doors would not close accurately if they were worked from the face or outside.

After the front frame has been fitted together as described, it must be taken apart, and the angle-stiles worked with plane No. 1. When this has been done,

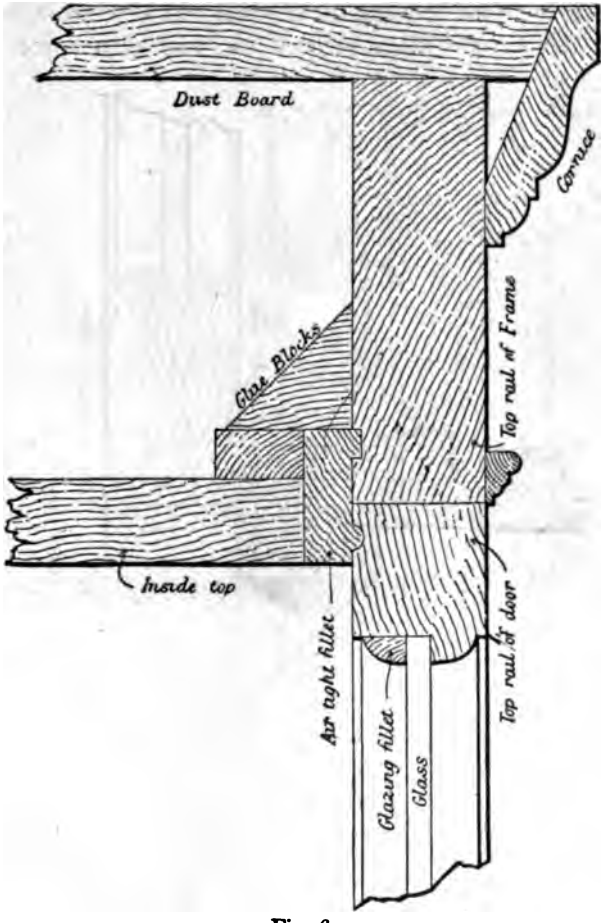


Fig. 6.

the fillets must be glued in the grooves, and, when set, rounded over with plane No. 2. The fillets will not require to be taken to the exact width before rounding over, as plane No. 2 works all surplus stuff away.

For the joint between the top and bottom rails of doors and the airtight fillets respectively, two planes are re-

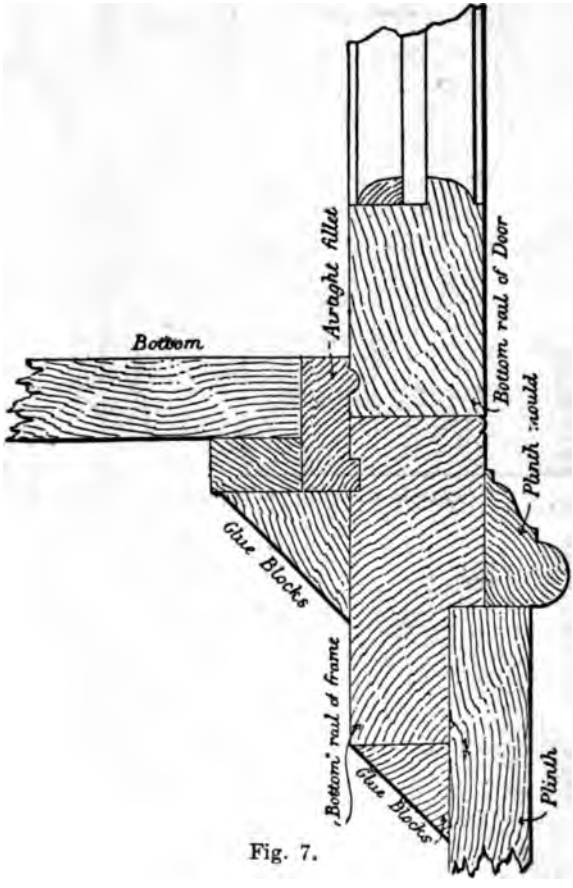


Fig. 7.

quired; the first for sticking the airtight fillet, and the second for working the small hollow on the door rails to match the fillet.

Continuing with the framework. After rounding the ets in the angle-stiles, groove the top and bottom

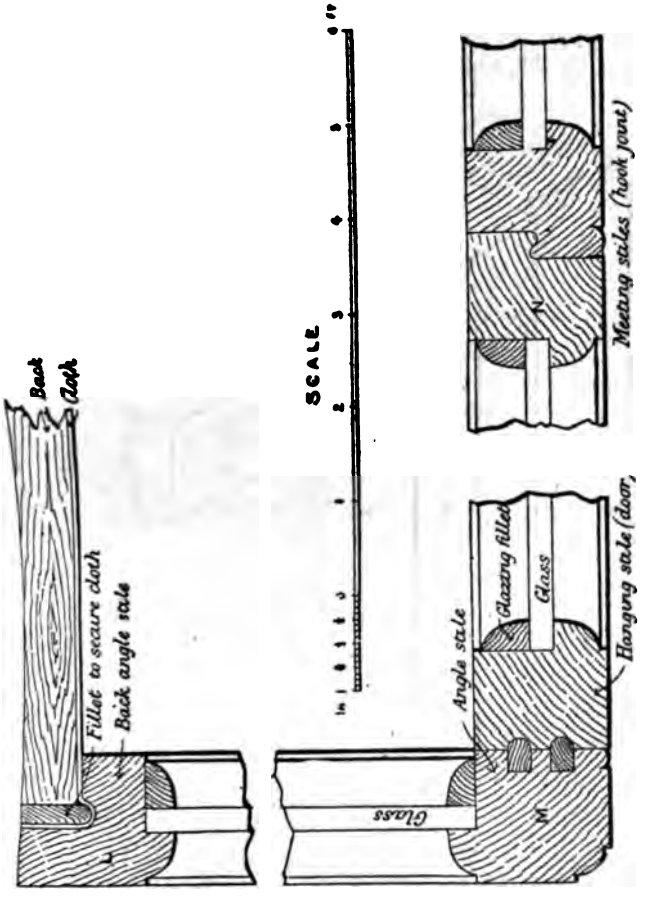


Fig. 8.

rails to receive the tongue on the airtight fillets as shown in Figs. 6 and 7 and rebate the bottom rails to rest on the plinth, Fig. 7. The top and bottom rails at each end

of the case are trenched to receive respectively the of the inside top and inside bottom, Fig. 5. Care be taken to make these trenches in such a way a keep the inside top and the inside bottom in the posi shown in the Figs. 6 and 7. Rebate the back angle

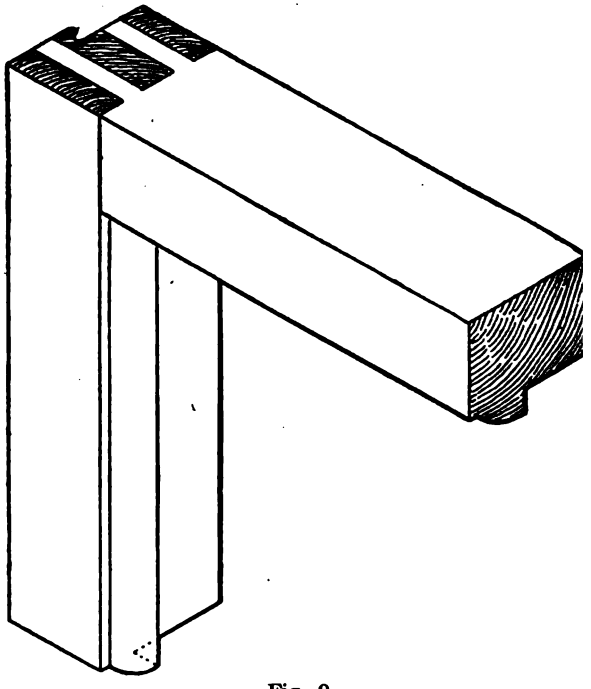


Fig. 9.

of each end frame to receive the back, as in Fig. 8, run a small hollow in the angle of the rebate. Glue pin the airtight fillet on the front edges of the i top and bottom respectively; also glue the fillet on back of each in order to strengthen the airtight fillet,

make out the thickness to receive the glue-blocks as shown. An ovolo or other moulding is now worked on the external angles of the two front angle-stiles as shown in Fig. 8, the moulding being stopped in a line with the top and bottom rails respectively of the doors, Fig. 1.

The body of the case must now be put together, care being taken to glue-block the front frame and ends securely to the bottom and top, as well as behind the plinth, which is screwed to the bottom rails from the back.

Match-boards are used for the back, the boards being run to the floor, as shown in Fig. 2. Mitre the cornice round the front and ends, screwing it from the back of the top rails; cut the dust-board to fit on the top edges of the rails and bevel against the cornice; having previously rebated it to receive the back of the case. Before the back is fastened, the cloth, Fig. 8, should be placed in the rebate of the stile, the fillet placed on top of the cloth and pressed into the hollow, and then fastened to the stile with screws, the cloth thus being securely held between the fillet and the stile. The cloth can now be stretched taut and fixed at the other end in the same way, and the boards fastened in.

Doors. In planing up the stuff for the doors, the same gauge must be used as that for the frame of the case. When setting out for the doors, take the width and height accurately, and allow 1/16 inch on the height for fitting in. The width is set out as for ordinary folding doors, viz.: allowing half the hook-joint on each door, and 1/8 inch for jointing and fitting in. The best way to allow for fitting is to have each stile 1/16 inch greater in width than the finished size required.

The rails abutting against each angle-stile are single-mortised and tenoned together as in ordinary work,

but double mortises and tenons must be used at the top and bottom of each meeting stile, as shown in Fig. 9. The reason for using the double tenon is, that if a single tenon were used, the ends of the tenon would slip off after the hook-joint had been made.

Presuming the doors to be wedged up, level off the joints at the shoulders, when the doors will be ready for jointing together and fitting to the case.

Hook-Joint. The following is the best method of making a well fitting joint. First rebate the stiles (the rebate being 1/8 inch less in width than the thickness of the doors, and 5/16 inch deep), and next bevel the edges of the doors, bringing the rebate to a depth of 1/4 inch, Fig. 8. The doors must now be worked with a hollow and round on the edge of the rebate to form the hook-joint. For this purpose a hook-joint plane is required. There is an adjustable depth-gauge on the side of the plane, which can be easily set for working different thicknesses of stuff. Before working the doors with the plane, it is advisable to work a piece of stuff of the same thickness as the doors. Cut the piece thus worked into two, and put the joint together. This will test the accuracy of the setting of the plane. If the faces do not come flush with each other, the gauge on the plane must be raised or lowered accordingly.

Having fitted the meeting stiles, place the doors together across the bench, as they can thus be more easily taken to the exact width and height of the frame of the case. After the doors have been fitted in the opening, work with the airtight planes as previously instructed, always remembering to hold the fence of plane No. 3 on the back side of the door while forming the hollows on the hanging stiles. With plane No. 2 the small hollow

on the top and bottom rails to match the airtight fillet is worked.

After working the doors as described, clean off the back side, place the doors in position, and clean off the face to the level of the frame. Take the doors out and

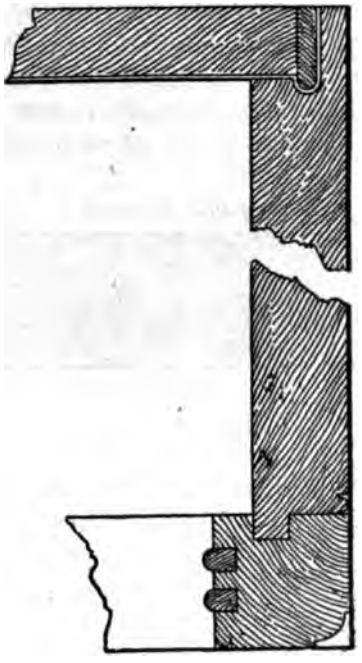


Fig. 10.

work the bead on the joint between the doors, Fig. 8. This bead is flatter than usual and has a very small quirk.

The doors are hung to the frame, each by three hinges. The top and bottom hinges are usually kept their own

depth from the top and bottom edges of the doors respectively, e. g., a 2½ inch hinge will be 2½ inches from the edge. The handles on the meeting stiles are respectively about 9 inches from the upper and lower edges of door.

All glass in the doors must be carefully packed with small slips of wood between the edges of the glass and the frame of the door, in order to keep the frame rigid. The woodwork being so slight, the doors would sag when hung if the glass were not packed tightly, as all the weight of the glass would fall on the bottom rail.

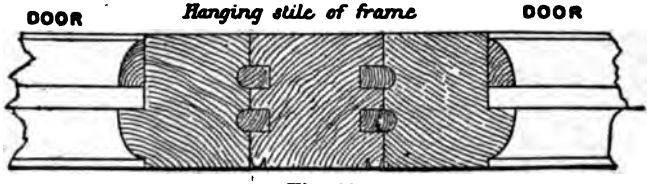


Fig. 11.

Shelves. The following is the best method to adopt for fitting the case with shelves, as, when fitted in this way, the shelves can be moved to any required height. To the back of the case screw two pieces of iron, one at each side, extending from the top to the bottom of the case. These must previously have been drilled and tapped their whole length, the space between each hole being ½ inch from centre to centre, and each hole being large enough to receive a 3/16 inch screw. A malleable-iron bracket about 3 inches long on the back edge—the length of the top edge being the width of the shelf—is now required, having a small piece projecting above the top edge in which is drilled a plain hole, and having a pin near the bottom edge. The pin at the bottom edge

is placed in one of the holes in the tapped bar, and a 3/16 inch screw is passed through the hole at the top edge and screwed into the bar, thus securing the bracket firmly. Care must be taken to have the same distance between the centres of any two holes in the bar.

Fig. 10 shows a horizontal section through a showcase having solid ends.

Fig. 11 shows a horizontal section through the centre hanging stile in the front frame of a wide showcase, when two pairs of doors are required. It is worked in the same manner as previously described for hanging stiles.

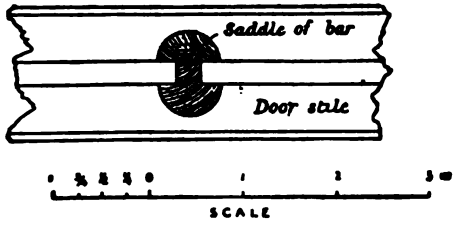


Fig. 12.

Fig. 12 shows a section of a cross bar in doors. This is only required where sheet glass is used. Each end of the bar is sunk into the moulding of the door-stiles. The saddle is cut between the rebates, and secured to the bar.

Plinths separate from the case. If the showcase is over 6 feet 6 inches in height, or the plinth is of a greater depth than 12 inches, it is advisable to make the plinth separate from the case. Instead of the bottom rail being rebated behind the plinth, as shown in Fig. 7, a frame must be made out of 1½ inch by 3 inch stuff dovetailed together at the angles; and two or three bearers should

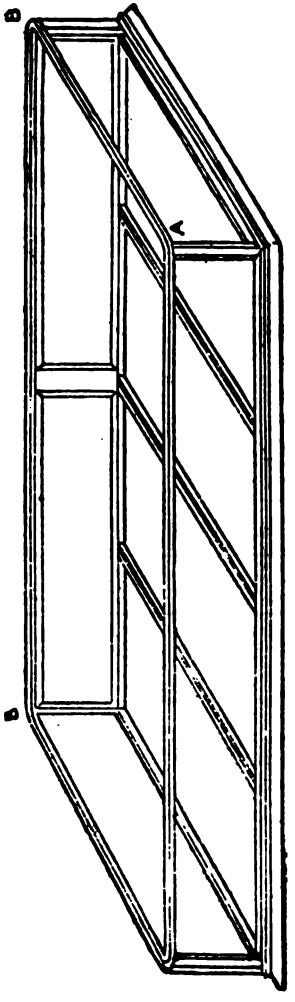


Fig. 13.

be mortised and tenoned between the front a
rails (as the length of the case may require).
angle, and under each end of the bearers, a leg i

tenoned into the under side of the rails to support the case. When this is done, the plinth should be mitred round the frame. It should be screwed from the back, and glue-blocks used in all the angles.

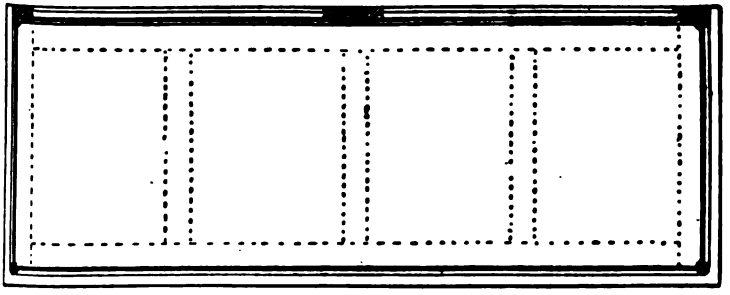


Fig. 14.

An isometrical projection of a counter-case is shown in Fig. 3. The top, sides, and front are of plate-glass. Mirrors are placed on the inside of the doors at the back of the case. The divisions on the bottom show the position of the trays.

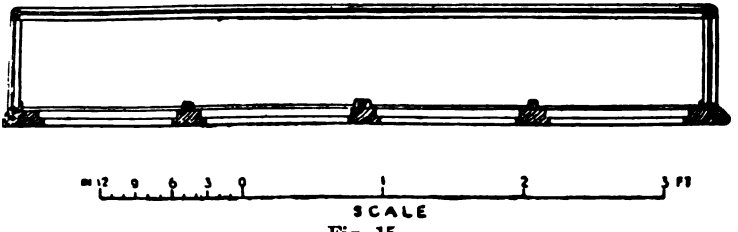


Fig. 15.

Before commencing work, it is absolutely necessary to draw Figs. 14 and 15 full size, to enable the taking off and working to an exact size of the various parts required to be done.

Bottom of case. Commence with the frame, which should be made out of well-seasoned pine. The width of the bottom frame will be the extreme width of the case less the thickness of the moulding on the front edge and 1½ inch for a hardwood slip on the back edge of the frame, Fig. 17. The length will be the extreme length of the case *minus* two thicknesses of moulding.

Mortise and tenon the frame together, and rebate it to receive ⅝ inch panels flush on the inside; then glue up and take to size. The hardwood slip can now be jointed and glued on, a tongued and grooved joint being used for the purpose. After this has been done, the air-

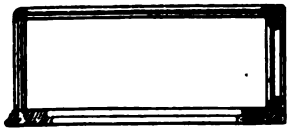


Fig. 16.

tight rebate to receive the doors should be worked on the hardwood slip. In order to make a good job of the rebate, it will be necessary to have a special plane for working both the rebate and the small half-round tongue at one time.

To complete the bottom, groove the front edge and both ends for the tongue, then mitre and fix the moulding to the frame. The moulding must be specially noted. It must project above the bottom 3/16 inch to form a rebate for the glass; and the first member, i. e. the part projecting, must be rounded to intersect with the upright angle-bars, Figs. 17 and 18, with mitre into the mouldings.

The panels in the bottom are to be screwed to the frame. Before putting the whole case together, they

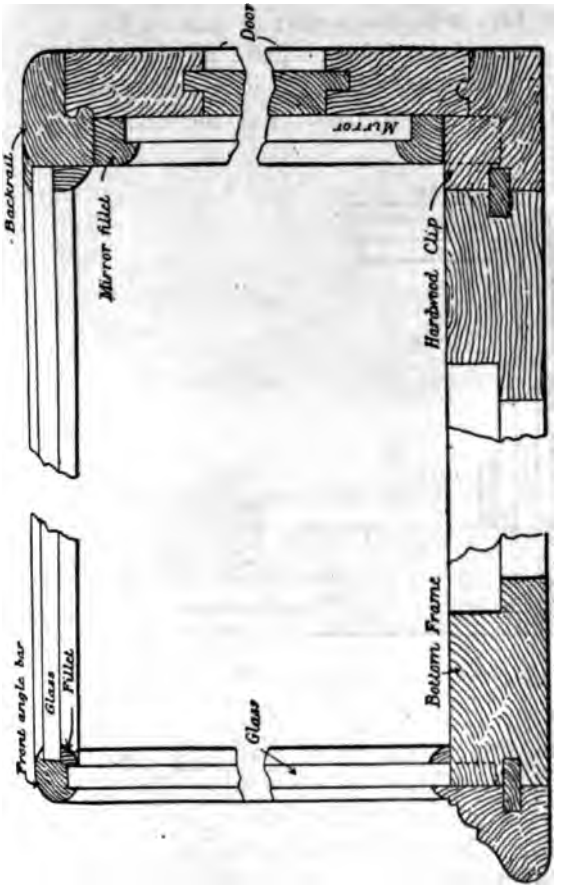


Fig. 17.

must be taken out for enabling the small fillets which secure the glass to be easily screwed into their respective positions.

Framework for glass. Plane up the stuff for the round angle-bars, gauging it to 9/16 inch square, and rebate ⅛ inch deep and ⅛ inch from the face edges. The angle bars will then appear as seen in Fig. 2. For the back part of the frame, square up the stuff to 1½ inch by ¾ inch and rebate ¼ inch deep and ⅛ inch from the face for the glass. For the doors, take out

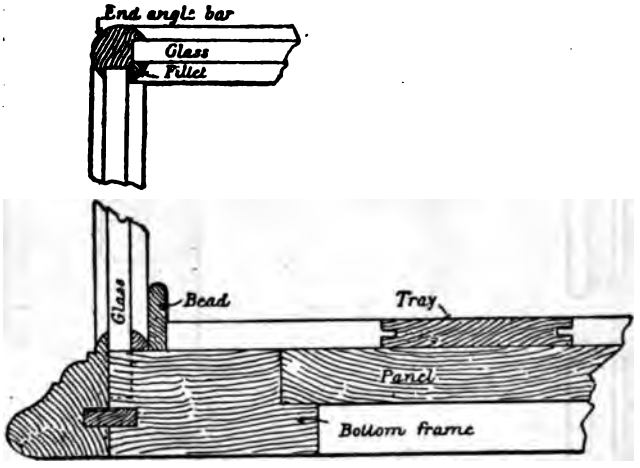
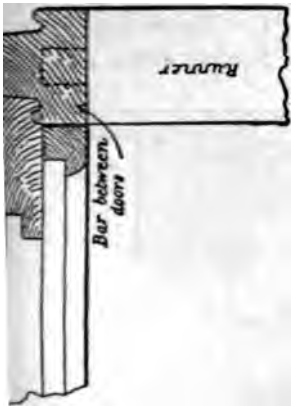


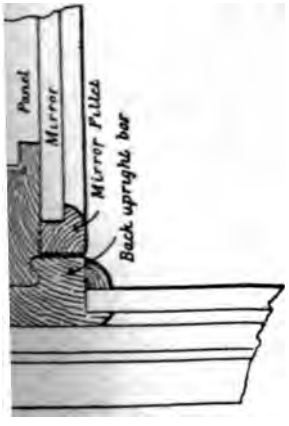
Fig. 18.

the rebate ¼ inch deep by ⅝ inch wide; bevel the rebate to 5/16 inch deep on the outside edge (as shown in Fig. 21), and work the hook-joint plane on the edge of the rebate. It is best to make the mitred joints first, as they require careful fitting together, and the bottom ends can be afterwards easily taken to the required length and cut.

Fig. 23 contains isometrical projections showing the

nts at the intersection of the front and the end angle-
s with the upright angle-bar. The position of the
nt is shown at A, Fig. 23.





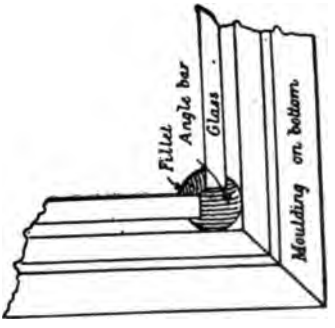


Fig. 19.

ree pieces of the required section, Fig. 20, should
t out, and the joint worked as follows:
mence with the front and end angle-bars, cutting

a square mitre, 45 degrees on each outside face of both bars, bringing the external angle to a point, as shown in the sketch. Cut the mitre down to the rebate line and cut the surplus away, leaving the core of the bar projecting, which will be the part C. The internal part of the mitre E is the sight line. Square down and across

Fig. 20.

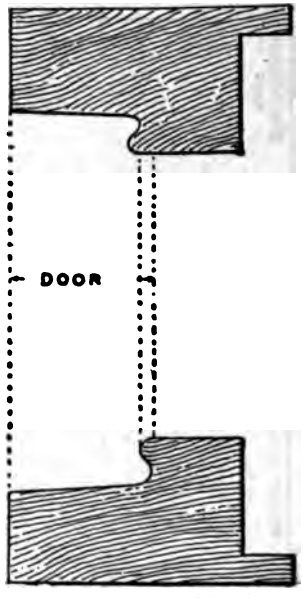


Fig. 21. Fig. 22.

the core; then, from the sight-line, measure distances of ⅛ inch and 7/16 inch; the resulting lines will be the shoulder and end of the dovetail respectively. Cut the core off at the longest line and form the dovetail as shown in the sketch, when the two bars can be fitted together.

Proceed with the upright angle-bar. Cut the square

mitre as before, but instead of cutting to the depth of the rebate, it must be cut 1/32 inch less. From the

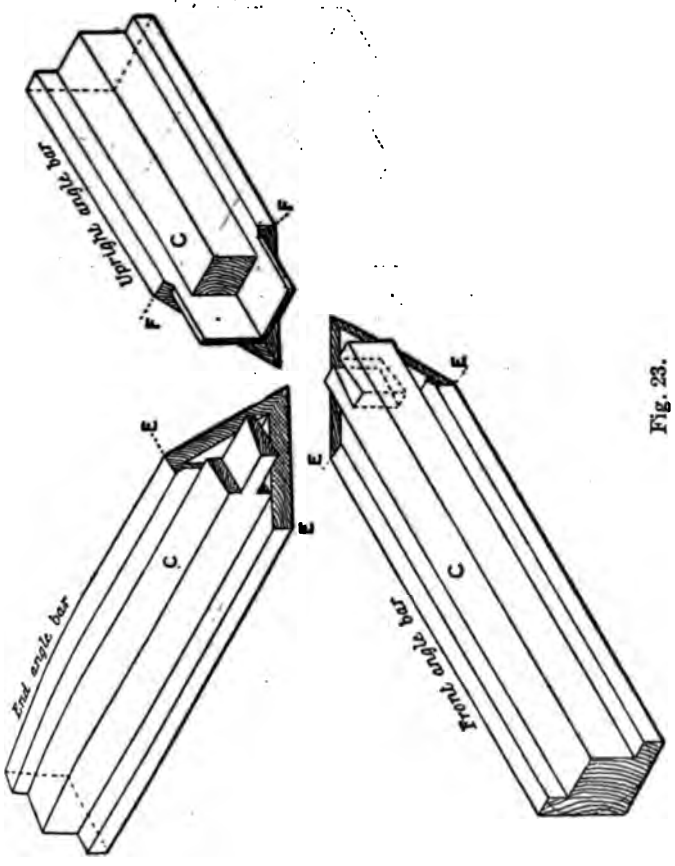
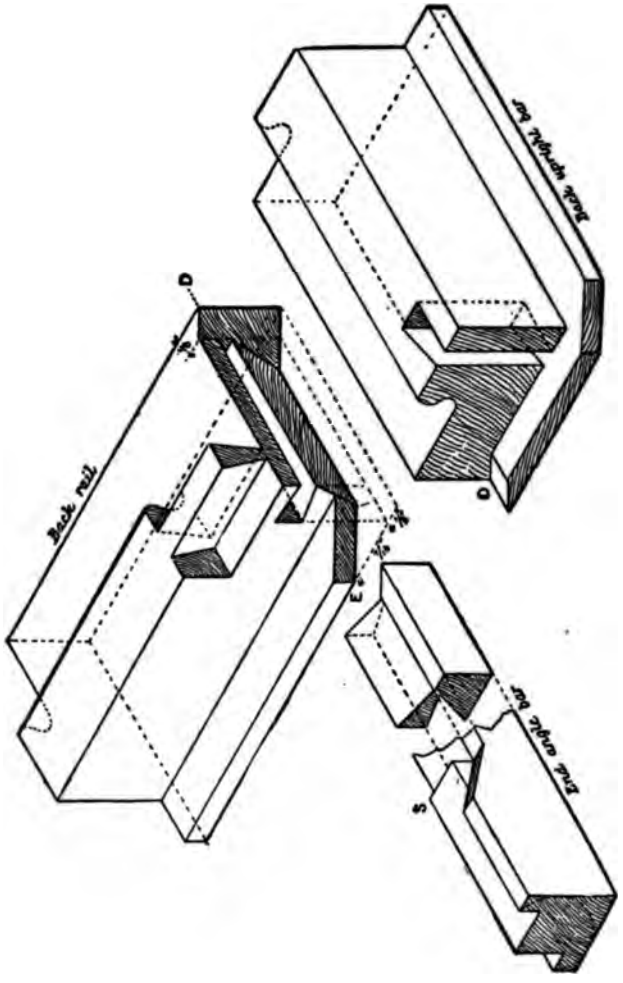


Fig. 23.

sightline F measure the same distances as before, viz., ⅛ inch and 7/16 inch. Cut off at the longest line, taking care not to cut through the projecting point of the


Back upright bar
D
Back rail
End angle bar
S

mitre, then take out the core C back to the shoulder line, thus leaving a thin tenon as seen in the sketch. Cut the tenon back 1/16 inch on each edge and continue the mitre through.

It will now be necessary to mortise the front and end bars to receive the tenon on the upright angle-bar. For the mortises, square a line across the mitre 1/16 inch from the sight line E. Gauge a line down the mitre 3/32 inch from the face of the bar, leaving 1/32 inch (the width of the mortise) between the core of the bar and the gauge line. The depth of the mortise will be to within 1/8 inch from the other face.

The work must be done very carefully, and great care taken to have the tenon on the upright angle-bar of the thickness stated, viz., 1/32 inch, as the result of having it of greater thickness would be that, when the bars were rounded, it would work through to the face.

The front angle-bar will have the same joint on both ends. The joint at the back of the case on the end angle-bar is cut as shown at Fig. 24. The joint at the bottom end of each upright angle-bar is simply a square shoulder cut to the depth of the rebate, leaving the core of the bar projecting to form a stump tenon. The bars are afterwards mitred with the moulding on both the front and the end, the projecting round of the moulding being cut away between the mitres in order to allow the shoulder to butt on the first square member, which will be flush with the bottom.

Fig. 24 contains isometrical projections showing the joints used to unite the back rail with the back upright angle-bar for forming the door opening; and also the end angle-bar. The position of the joint will be clearly understood by referring to B, Fig. 13.

It will be well to follow the same system as in the last group of joints, i. e., to prepare a piece of the required section of back rail, Fig. 21, which, when cut into two parts, can be used for both the back rail and back angle-bar; the only difference in the section of the two being that the back rail is rebated 1/16 inch less than the thickness of the doors instead of ⅛ inch less as in the back upright bar, Fig. 22. The reason for this is to allow the

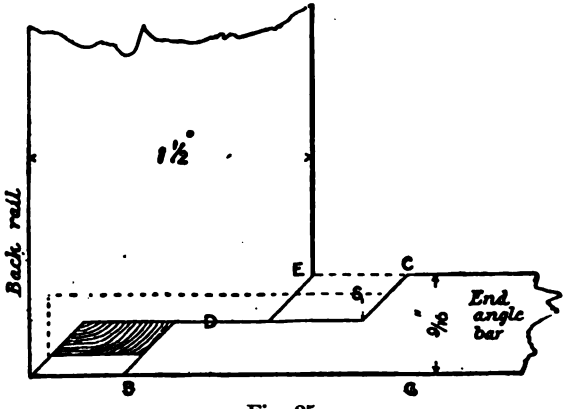


Fig. 25.

round of the hook-joint on the back upright bar to project over the hook-joint on the back rail which butts against it. It also allows a continuous hollow on the edges of the doors, which would not be the case if the rebates were kept flush with each other.

The end angle-bar is dovetailed into the back rail and is also mitred both at the extreme end and at the rebate. Fig. 25 shows the plan of this joint. It will be observed

that the joint has been left open to show the bevel from the shoulder line to the dovetail on the back rail, as at A, Fig. 31.

The back rail is also dovetailed to receive the upright bar. If the reader will look at Fig. 24 and imagine the upright placed into position on the back rail, he will notice that D D meet and form the remaining part of the

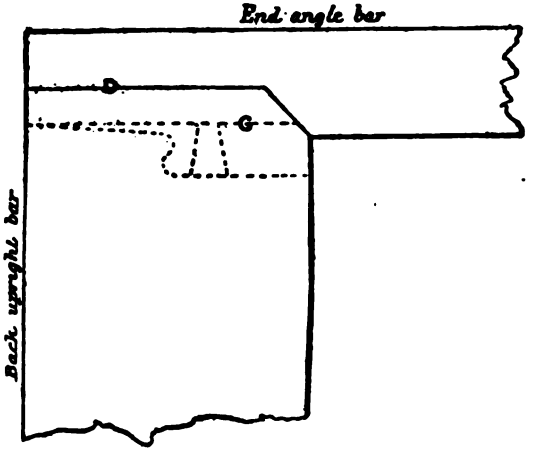


Fig. 26.

mitre, leaving a shoulder and mitre to join the end angle-bar when in position. The exact position of the latter is seen in Fig. 26, the dotted lines showing the position of the dovetail on the back rail.

We will now proceed to set out the work.

Commencing with the end angle bar, square off a line for the extreme end of the mitre at B, Fig. 25, and measure back the width of the back rail (namely 1½

inch) to C, which will be the sight line. From the sight line set off 5/16 inch for the shoulder of the dovetail as at S, Figs. 24 and 25; then set off 1⅜ inch from the sight-line to the end of the dovetail. Set a gauge to the centre of the angle-bar for the shoulders, as at D, Figs. 25 and 26. The shoulder at D, Fig. 25, is cut under on the bevel as shown in the section through the joint at A, and in the sketch of the end angle-bar, Fig. 24, where the drawing is broken. It is necessary to bevel it in this way in order to obtain the requisite strength in the dovetail. The shoulder on the side, Fig. 26, is cut square, as shown in the sketch. Mark the mitres, cutting from the sight-line to the shoulder line. The mitre on the extreme end is cut through as shown in Fig. 25.

To set out the back rail as shown in Fig. 24, square a line for the extreme end of the mitre, and from this line measure back for the sight-line, namely, 9/16 inch, the width of the angle-bar, as at E, Fig. 25. Square a line between the two lines obtained, at an equal distance from each for the shoulder D. From E measure 7/16 inch toward the end of the bar, and cut off square to within ⅛ inch of the outside edge; this is clearly shown in Fig. 24.

To mark the dovetail of the end angle-bar, make a thin hardwood or zinc pattern to fit the dovetail on the angle-bar and apply it to the rebate of the back rail, cutting the dovetail out very carefully to within ⅛ inch of the outside edge. On the top side of the rail mark the external mitre from the extreme point to the shoulder-line, and cut as shown in Figs. 24 and 25. Before the mitre can be completed, the bevel must be cut along the shoulder-line and edge of dovetail, and must work

out against the mitre. The internal mitre is cut from the sight-line.

There now only remains the cutting of the dovetail to receive the upright bar. Referring to Fig. 24, it will be seen that it is necessary to obtain the shoulder-line only, which is accomplished by measuring from the extreme point of the mitre, D, Fig. 24, ¾ inch, the thickness of the upright bar. The position of the dovetail-joint between the back rail and the back upright bar is shown by the dotted line in Fig. 26.

Exact lines for setting out the back upright bar, Fig. 26, are found as follows: Square the shoulder-line D and set off for the back shoulder ¼ inch as shown by the dotted line G. The back shoulder is then cut off to within ⅛ inch of the face, as in the sketch, Fig. 24. Make a pattern to fit the dovetail on the back rail, and apply it to the back of the bar. Mitre the ¼ inch projection on the outside edge, and also mitre the inside as shown.

It is absolutely necessary that the whole of this work should be executed very carefully and very neatly. When the above mentioned joints have been fitted, make the bars to the required length.

To set out the bottom end of the back upright bar, cut the face shoulder square and mitre with the moulding as previously described for the front angle-bar. Allow the back-shoulder to be ¼ inch longer, so as to fit the rebate for the doors, the tenon being in the position shown by the dotted lines in Fig. 17.

After all the joints have been made, round the angle-bars and the back rail. The external angles of all upright angle-bars must have the rounding turned out about ½ inch above the bottom shoulder, leaving the

bottom part of the bar square to follow the line of moulding. The joints can now be glued together a cleaned off.

The double-rebated upright bar between the doc as at H, Fig. 19, is cut to give both the top and bott rebate, a small dovetail being cut at both ends in positions shown by the dotted lines. The front edge the bar is slightly rounded to break the joint betw the doors. From the inside of the bar a runner of same thickness as the bar is screwed to the bottom the case to keep the trays in position.

Doors. There is nothing special to note in fram up the doors; they may be either tenoned or dowel together. The panel is prepared flush on the inside.

Carefully fit the doors to the opening and work hook-joint on the top edge and both ends. It will remembered that the hook-joint must be worked throu on each end; and also that it is deeper than the ho joint on the top rail. In working the small hollow fit over the fillet on the bottom edge, work the pl from the back side of the door.

Hinge the doors on the bottom edge, fixing the bu against the outside edge of the half-round fillet. Wh fixed thus the airtight joint will remain intact. T doors are fastened by a spring catch or lock let in the top rail.

When the doors are hung, the position of the mir fillet can be marked by lining down the back of t doors round the frame. The fillets should be fixed 1/ of an inch inside the lines to allow for clearing.

Trays. A cross section of the tray is shown in F 18. The bottom is prepared for three pieces of ¼-in pine. The grain of the centre piece runs from back

front of the case, the grain of the side pieces being at right angles to it, and the three pieces are tongued and grooved together as shown. Glue the pieces together, and, when set, mitre the bead round the bottom.

Another method of ensuring the bottom against warping is to have the bottom in three thicknesses, the grain of the centre lying across the two outside pieces, and the pieces being glued together.

The inside of the tray and over the bead are covered with velvet or some other material, which must be glued to the tray. Glue should be used sparingly so as to prevent it penetrating the material.

CIRCULAR-FRONTED COUNTER-CASE WITH GLASS ENDS.

Fig. 28 shows a cross section through a circular-fronted case with glass ends. The only difference in the construction of this case from that of the square case is the bent angle-bar, and, of course, the omission of the front angle-bar.

In making this case it is first necessary to have the glass bent to the shape required. For this purpose a pattern of the curve should be sent to a glass manufacturer. When the glass has been received make a mould of the same shape, on which to bend the angle-bar, as shown in Fig. 29. The convex side of the glass will give the rebate line from which to work the mould.

Use birch for the angle-bar, as it bends easily; it can be stained to match the other part of the case. Have the bar long enough to bend from the bottom of the case to the back rail.

To bend the bar successfully, cut the top side of the bar away down to the rebate line on the end required

to be bent. The length of the part cut away from the bottom of the case to a little beyond the ing line. Care must be taken to cut the two

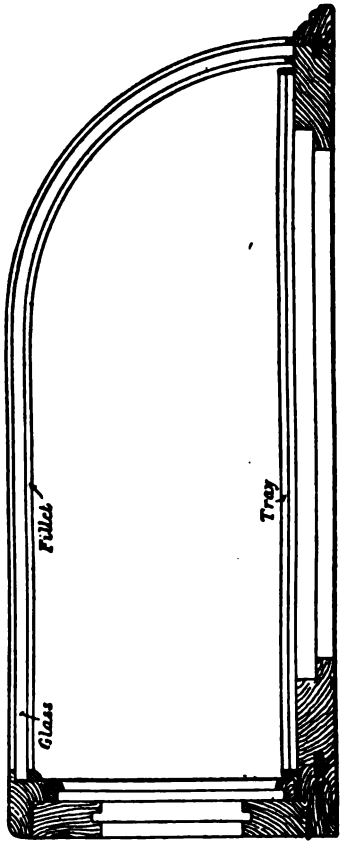


Fig. 28.

the case in pairs. Steam the bars for several ho then bend them round the mould (Fig. 29) by s the extreme end first with a cleat, as shown at A.

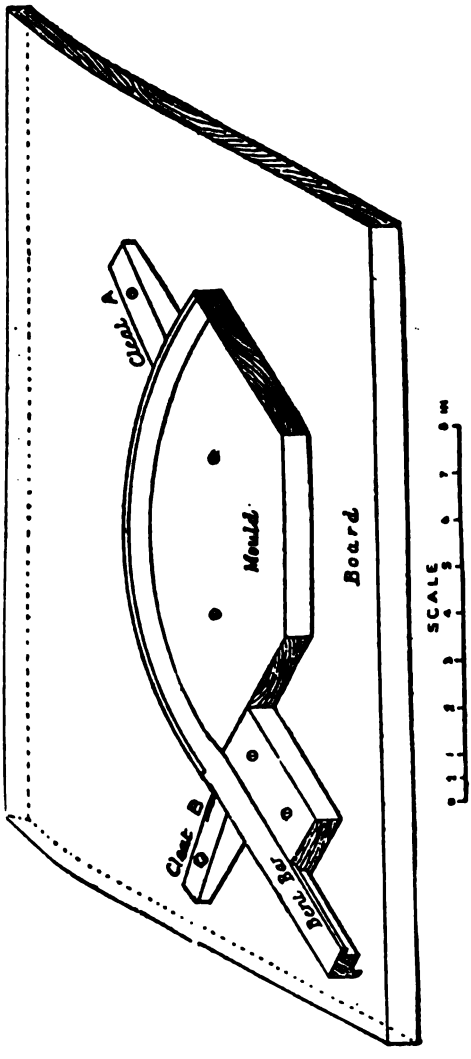


Fig. 29.

the bar gradually to the mould, secure it in position by the cleat B, and leave it to cool for several hours. It is better to leave it on the mould until the following day, when the strip to form the rebate—which replaces the part cut away—can be fitted and glued in position.

After the bar has been bent and the strip cleaned off, place it on the drawing-board and set out the position of the joints at the bottom of the case and on the back rail, as already described.

CIRCULAR-FRONTED CASE WITH SOLID ENDS.

It will only be necessary, after the preceding explanations, to notice the joint of the back rail, and the section

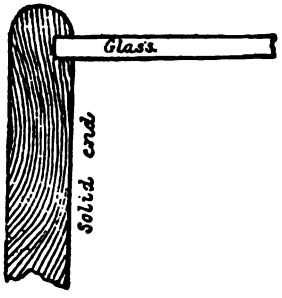


Fig. 30.

of the solid end. Fig. 30 shows a section through the solid end of the case, grooved to receive the glass. Fig. 31 is a plan of the angle formed by the end of the case and the back rail. The clamp A is tongued and grooved to the end, the tongue being stopped ½ inch below the top edge. The clamp is prepared with a hook-joint as shown by the dotted lines. The width of the clamp is the width of the back rail less the rebate for the glass.

ig. 32 shows in isometrical projection the joint at junction of the back rail with the solid end. Imagine

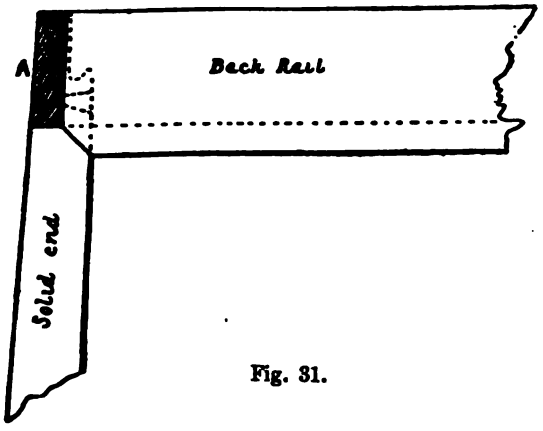


Fig. 31.

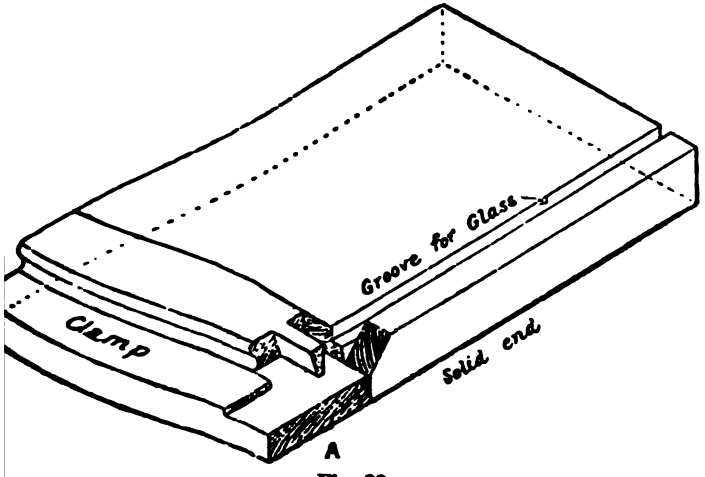


Fig. 32.

t A A are brought together. It will then be seen t they slide into position and present the appearance

shown in the plan in Fig 31, and give the extra lines for setting work.

The solid ends are ⅝ inch thick, finished size. They must be left wide enough to screw to the bottom frame of the case. Fix the moulding round the bottom and mitre it at each inside round of the ends, as before described for upright angle-bars, turning the round on

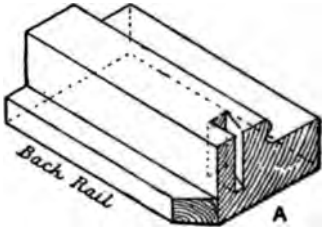


Fig. 33.

the outside of each end out ½ inch above the moulding. The moulding mitred round the ends of the case must be reduced by the thickness of the quarter-round member which forms the rebate for glass at the front of the case.

These cases are often fitted with several trays, the bearers to carry them being screwed to the ends.

SOME FORMS OF PANELS.

We conclude this Volume by giving some illustrations of panels. In Fig. 1 we give a "flush" panel for a front or entrance door, in which in front elevation a, b, are the two rails, d d, e e, the stiles, c c, g g, the panel with

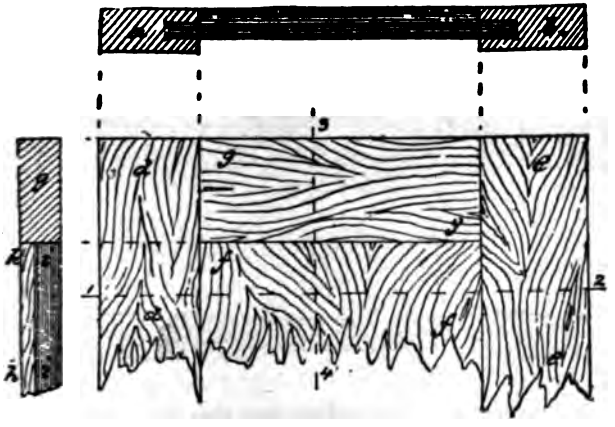


Fig. 1.

stuck-on mouldings all round and mitring at corners; g h is a vertical section in line 3 4. In this the recess between the stile and panel is one side only. Where there are recesses on both sides of the panel b b, Fig. 2, and the stiles a a, the panel is known as a "square" panel. In this figure the lower diagram is front elevation; that on the left is a section on line 3 4. In Fig. 3 we illustrate different forms of panels. In the upper diagram, a a, the stiles carry one "square panel,"

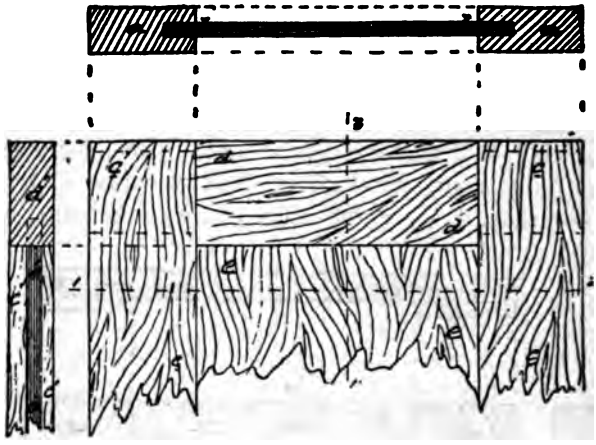


Fig. 2.

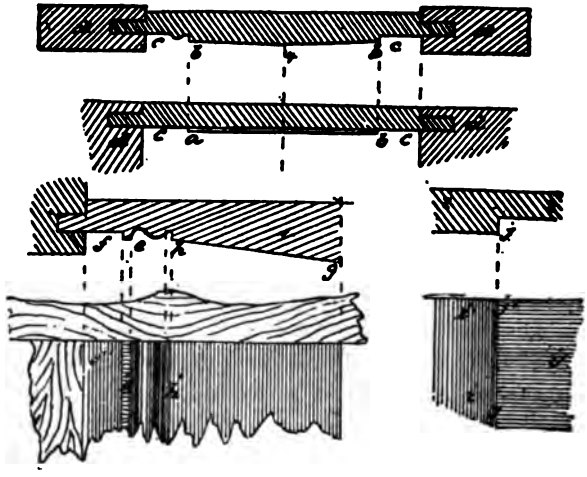


Fig. 3.

which is not flat, as in Fig. 2, on the inner side, but tapers to the centre, which is thickest, to the sides,

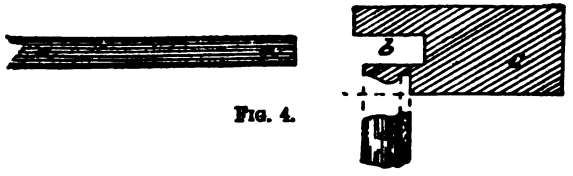


Fig. 4.

where it may be either square, as at the right hand, or finished with a moulding, as on the left.

Resuming our description of the drawing named, the second diagram shows a "flush panel," with stiles d d,

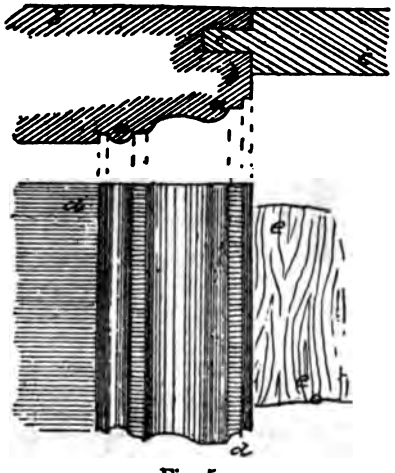


Fig. 5.

the panel having a raised position in the centre, as shown at a b, with flat spaces as at c c, all round. The

lower diagram to the right is an enlarged view in section and elevation of the part of the panel of upper diagram to the right. The lower diagram to the left is an enlarged view of the left hand side of the panel, which is technically called a "raised panel." Figs. 12 and 13 are other views of raised panels, and diagram

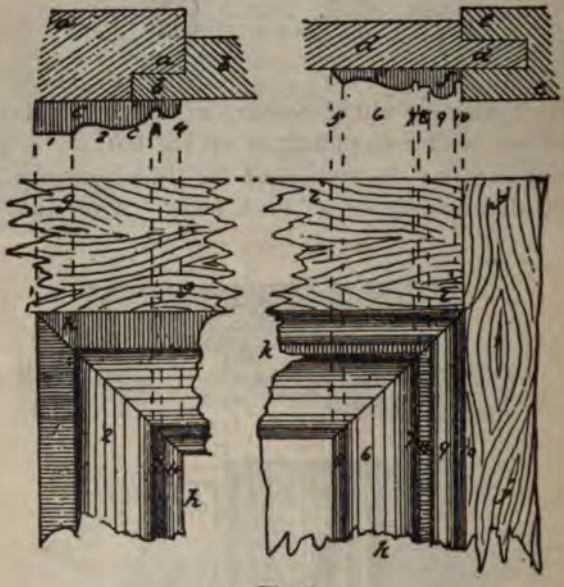


Fig. 6.

B in next figure shows a form of panel in the Gothic. Other forms are illustrated in Figs. 8, 9, 10, and 11. In Fig. 3 the flat part of the panel surrounding the raised central part is called the "margin." (See also Fig. 12 at b.) The panel, as in Fig. 3, is called a "moulded raised panel" when there is a moulding at

the margin, as f e h. There are other distinctions in panel work, yet to be noticed. In "flush panels," as in Fig. 1, the "moulding" or "bead" is worked only on the two sides (vertical) of the panel, as at d d, Fig. 5, and these terminate at the rails, as at f f, no moulding being at the ends of the panel. This is called "bead butt" panel. When the panel has mouldings all round,

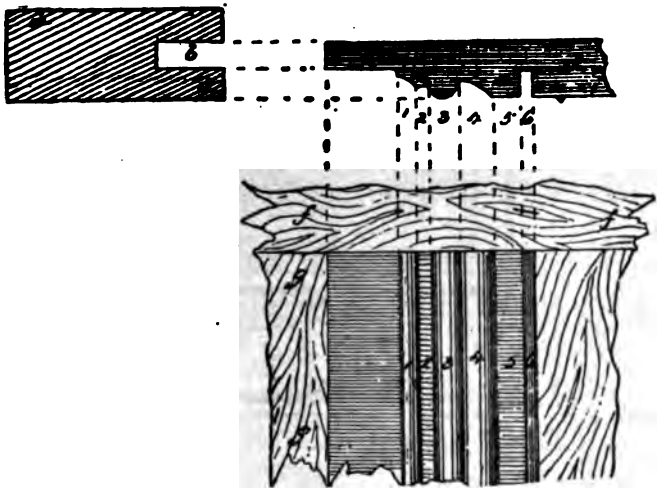


Fig. 7.

that is at top and bottom as well as at the sides, the mouldings meet at the corners and are mitred, as shown in the lower part of the diagram in Fig. 6, this is known as a "bead flush panel." In panel work where a moulding is worked out of the solid, as at b in Fig. 4, or at a a in Fig. 5 of the style, as c c or b b, the term "stuck on" (a corruption of "struck on," which

is the true term) is applied. This is only applicabl
"bead and butt" panel work vertically, as the mo
ings would not mitre if struck horizontally on the

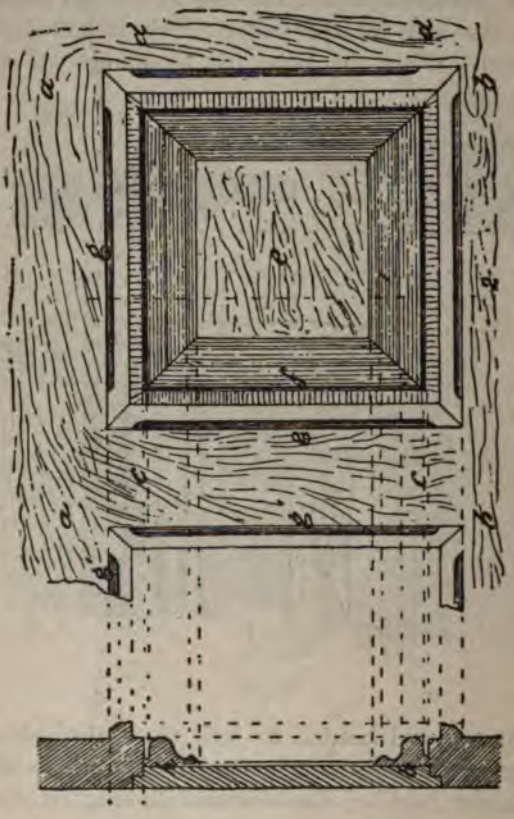


Fig. 8.

When the mouldings are made separately and na
onto the stiles j j, and rails i i, Fig. 6, they are ca
"laid on" mouldings. They may be nailed on eithe

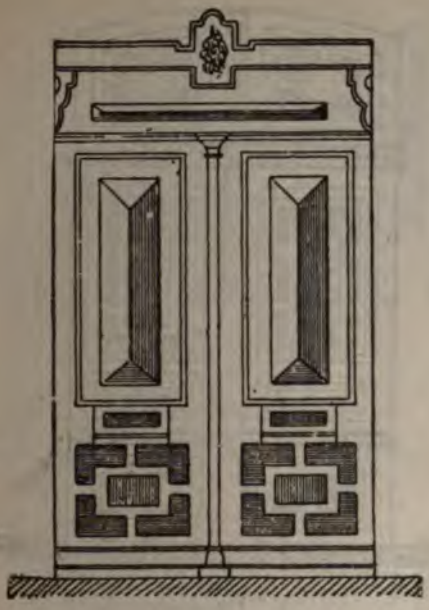


Fig. 9.

Fig. 10.

JOINERS' WORK IN THE CONSTRUCTION OF DOORS—DIFFERENT KINDS OF DOORS.

We now come to illustrate the different forms of doors, and various details of their construction. Doors are either external or internal and both may be con-

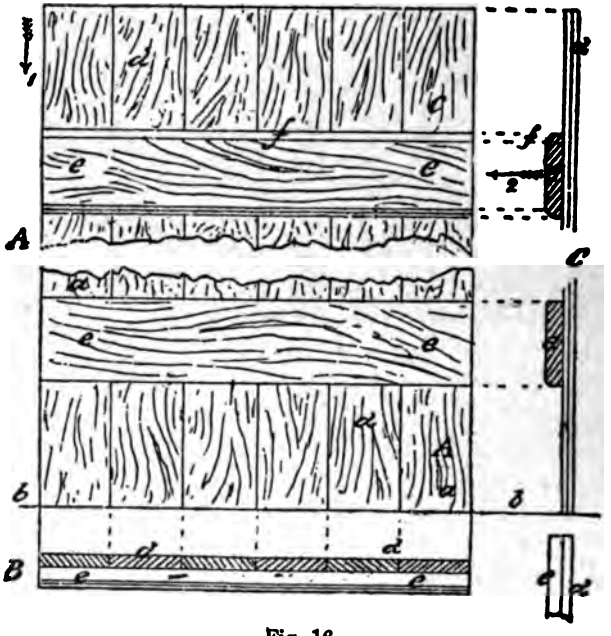


Fig. 16.

structed much in the same way. The chief difference between them, if difference may be made at all, is that external doors are heavier in their timbers—that is,

thicker and broader—and are not quite so much ornamented with mouldings, or so highly and carefully finished, as internal or private room doors. Doors are of different classes, beginning with those adapted either for houses, of a simple character or for out-buildings, etc., where economy is carefully studied, and going up to the more elaborate forms, used in houses of the higher class.

The simplest form of doors is shown in part elevation at A, Fig. 16, in plan at B, looking down in direction of arrow 1, in C side elevation or edge view looking in direction of arrow 2. This form is what is called a "batten door." In elevation in diagram A, the lower part is a a, next to floor or ground line b b. The door is made up of flat planks, a a c d d, running vertically from foot or floor, or ground line b b up to head. These are either laid as in plan B in the cheapest class of work, edge to edge, and held together by cross pieces, or bars, e e. In better work, these and the vertical parts, d d, are secured by joints of different kinds. In the section C the cross bars e are simply laid flat and nailed to the upright planks, d d. The edges of the cross-bars, d d, may either be left square, or have the lines or corners planed off and "chamfered" or beveled off as at f f.

BATTEN AND BRACED AND BATTEN, BRACED AND FRAMED DOOR.

Fig. 17 is an elevation in diagram A of a "batten and braced" door. To the vertical and cross bars of the simple form in Fig. 16 the diagonal "brace" a a a a,

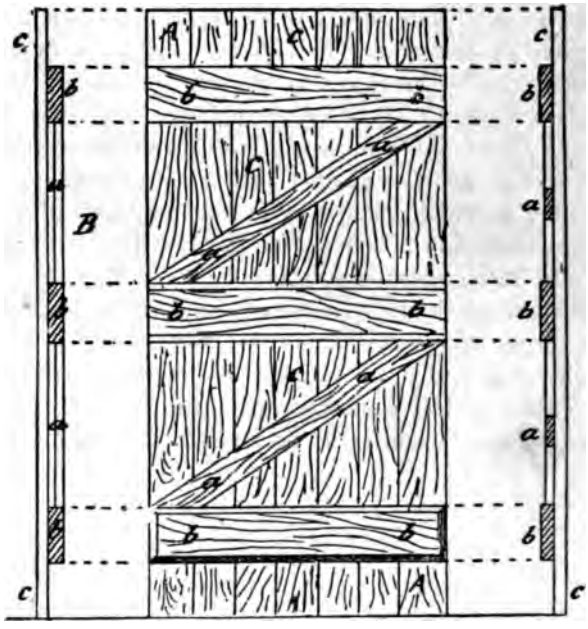


Fig. 17.

corresponding to the struts of a roof truss, are introduced; these butt against the cross bars or battens b b b b, while behind are the vertical boards c c c c,

Diagram B is side elevation or edge view and C vertical section. A still higher class of door is the "framed

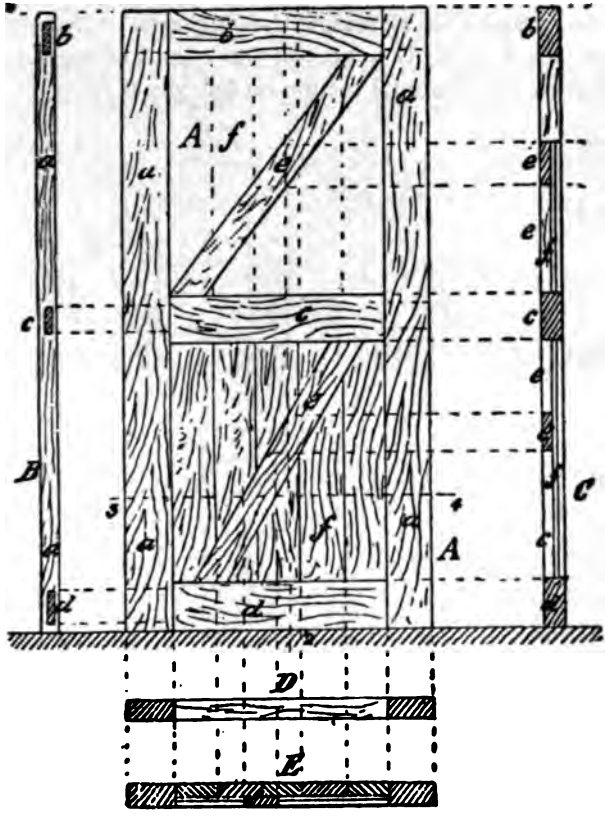


Fig. 18.

braced and battened" door, in Fig. 18, here as in elevation in diagram A, we have an outer frame vertical

pieces, held together and secured by the cross-bars b, c, d, the ends of these being tenoned into the stiles a a. The central spaces are filled with braces e e, and the vertical boards f f. Diagram B is vertical section on line 2 and C is side view showing ends of tenons of cross bars b, c, d; D is plan of top edge, looking down; E is cross or horizontal section on line 3 4 in A.

PANELLED DOORS—NAMES AND OFFICES OF DIFFERENT PARTS—STILES—RAILS—MORTISES.

The transition from this form of door to the highest class, the "panelled door," is easy and natural. We have

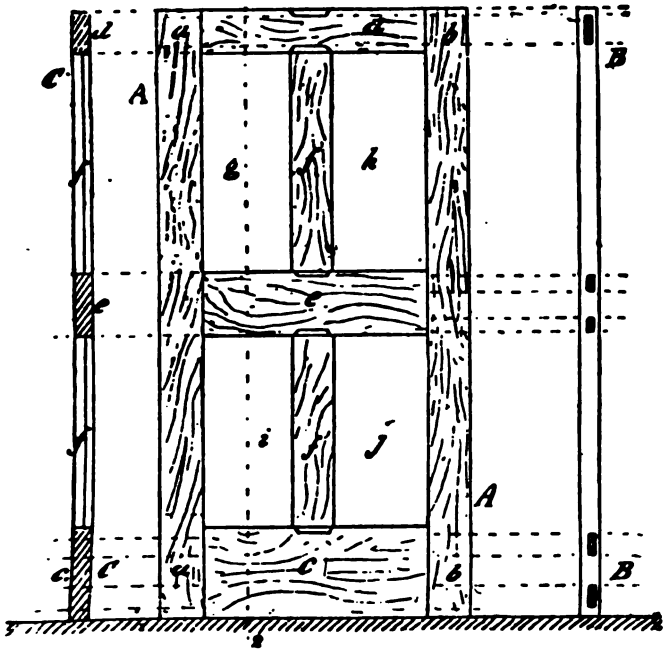


Fig. 19.

seen in the simplest timbers, which is the element of the "truss," and which gives the strongest form attainable.

In this view the panelled door, as in elevation in A, Fig. 19, is not so strong as the form in Fig. 18, from the absence of the diagonal braces, as e e, but those, if required in a door such as an external one, where strength is an object can be dispensed with in interior doors, which are always panelled in good houses.

Elegance or neatness of arrangement, with such ornamentation as mouldings, etc., can give, are what are looked for. In Fig. 19, the external framework enclosing the panels is made up of two side vertical boards, a a, b b varying in thickness from 1½ to 2½ inches, and in very superior work even 3 inches. These boards are called "stiles"; that by which door is hung to the casing, secured by hinges is called the "hanging stile," as a a; that to which the lock is secured the "lock stile," as b b. These stiles are held together by cross-bars called "rails" of which c is the "bottom rail," d the "top rail" and e the "middle or lock rail." The central vertical bars, as f f are called "muntins" (a corruption of mouldings). The assemblage of boards thus arranged leaves spaces as g, h, i, j, these are filled with panels, as a, b, c and d, in Fig. 20, which is the elevation of a *four*-panelled door. There are also six-panelled doors. Generally the panels are nearly equal in length, but in some the lower panels are short, the upper being longer. Figs. 2 and 4 illustrate outside doors in Continental style. The panels are secured to the framing by grooves, as shown in preceding figures and as further hereafter illustrated, and are ornamented with mouldings, as explained. In Fig. 19 diagram C is the vertical section, edge view of style b b. In Fig. 20 B is plan of top edge of door. The rails are secured to the styles by tenons, sometimes single, but more frequently in good work

by double tenons, as in Fig. 21, in which is front elevation of rail, a a, b c two tenons. Diagram B is part of stile a cut vertically in two to show the seats of the mortises b and c, diagram C and view of rail. In left-hand dia-

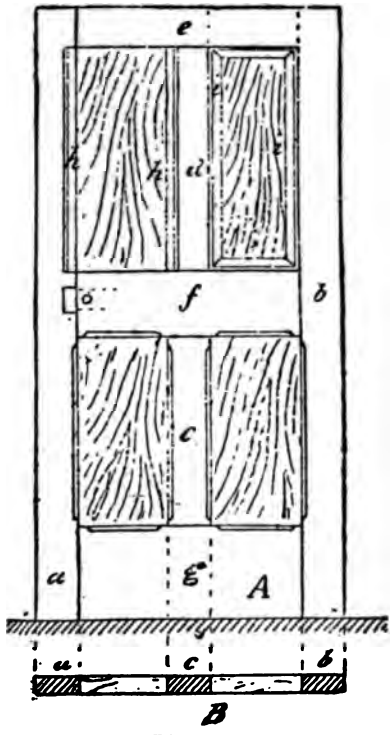


Fig. 20.

am in Fig. 12 is elevation of part of "lock stile," a a d "lock rail," b of a bedroom door, with simple lock, known as a "rim lock." In diagram B, part of the anging stile," a a, of this door is given in elevation, b

part of "top rail," a portion of upper "hinge" is shown at c. Diagram C is edge view. The inner edges of stiles, rails, and mortises are generally, in good work, "stop chamfered" as at d d, or beveled off from end to end, as at e f, the two edges meeting in a mitre, as shown. The "top chamfer," d d, is the neatest, stopping, as it does, short of the end. A rim lock is screwed onto the outside of the lock stile; what is called a "mortise lock" is employed in superior doors, where the lock is concealed, nothing but the handle and keyhole being visible, the lock being inserted in a mortise or vacant part cut out in the stile to receive it. Fig. 29 contrasts the two locks. c d is the rim lock. In the mortise lock nothing but the handle at g is seen, and the escutcheon h, i is the bolt of the lock, a a, b b, a′ a′, b′ b′, are the chamfered stiles and rails.

DOOR CASINGS.

Doors are secured to "casings." These are of timber, and built into the walls, and are secured to wood, bricks or grounds. Fig. 23 illustrates in part elevation an outer "door casing." The sides b b, c c, are called "jambs," f f, the "head," into which the jambs are tenoned, the feet being also tenoned, at d, into the upper part of stone step a a. Fig. 22 is sectional plan showing arrangement and relative positions of various parts of a door and its casings. The door, l l, is hinged to the "jamb" b, this being secured to the "ground" or "wood brick" a a, bulit into the wall b b, c and j are the "architraves." The opposite "jamb," f f, is rebated as at m to allow of a space into which the "door lock stile" falls, as shown by the dotted lines, which represent the lines of the door. The outer edge of the jamb may be left plain, but is often finished off with a "quirked head," as at j; k, k, the hinge. The inner and outer architraves are at c and j; a a, the wood brick; b b, the wall; e, i, are the elevations of the architraves, d and h. The elevations of these two parts of sectional plan of door fittings are given in the under part of the drawing in Fig. 23. The edge of the door a, as looking at it from the inner side, is shown at p p, q q, being the ends of tenons of top rail, r r, the hinge, n n, from a view of architrave, o o the wall in the void of which the door is hung. In the under drawing to the right, part of front surface of door is shown, s s, the architrave, t t the wall.

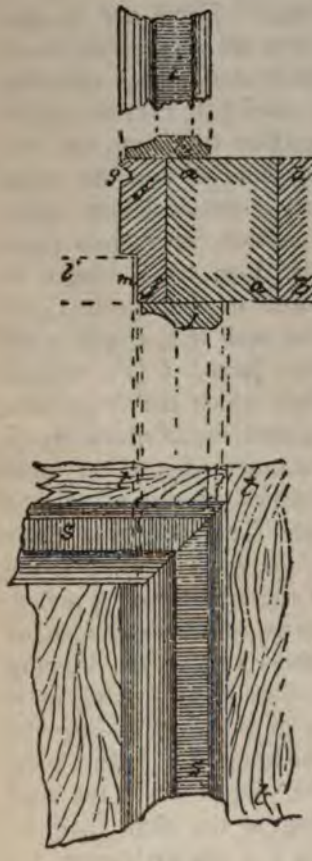


Fig. 22.

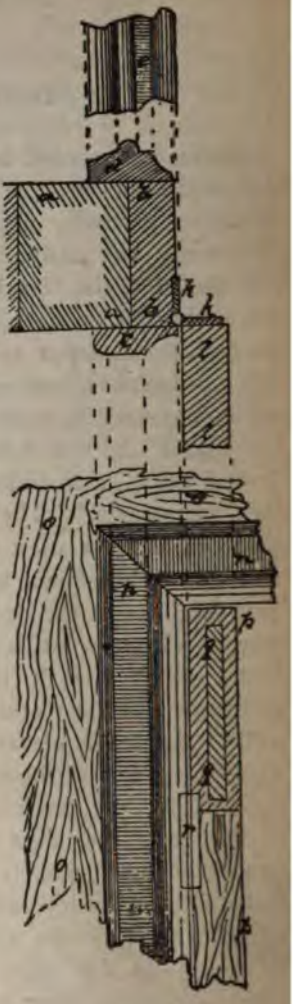


Fig. 23.

JOINTS OF STILES AND RAILS IN PANELLED DOORS.

Figs. 24 and 25 give illustrations of methods of joining rails and stiles, or rails and mortises. Let a b c d, Fig. 24, be the stile, with moulding stuck on edge; f g h s part of the rail, with tenon f, shown by dotted lines

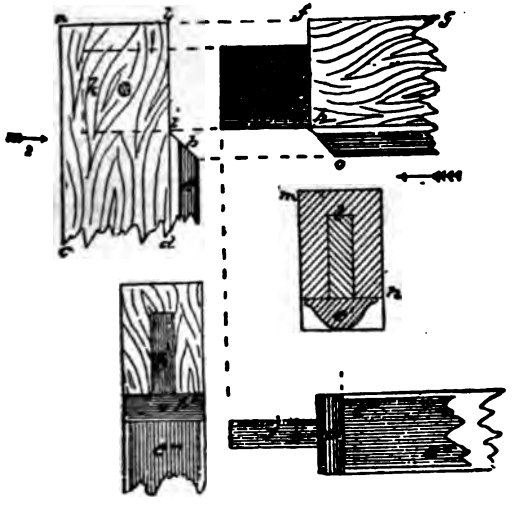


Fig. 24.

tile a b c d. Front view of tenon are face of mitre hamfer at p, looking at a b c d in the direction of w 1, is shown in the lower diagram at k′, p′ and e″. section of part f g looking at its end, in direction of w 2, is shown at l m n; the section of a moulding

is in this at e'. In lower diagram to the right is given a view of under side of rail f g. In Fig. 25, a a, is

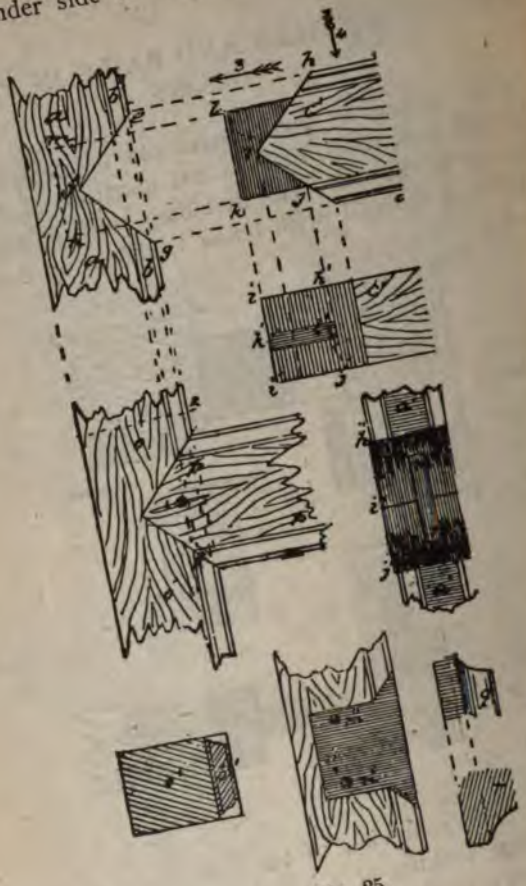


Fig. 25.

front view of part of stile with moulding edge, at b b; part of rail is at c' c' d.

face of part cut out in stile e f, fg corresponds with angular end h i j of rail, but a tenon i l k is left on, or is inserted in end of piece c′ c′ d. The end view of the stile a a, looking at it in the direction opposite to that

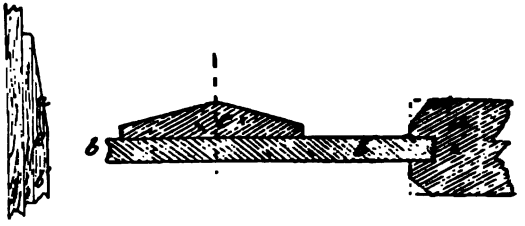


Fig. 26.

of the arrow 3, is shown in the middle diagram to the right with corresponding letters accented, showing corresponding parts. The line i″ i″ corresponds to the line at point in rail c′ c′ d d. The plan of under side of rail c′ c′ d is shown in diagram immediately below it, l being edge view of tenon k l. The finished joint is shown at o o, p p; the diagram below to the left being cross

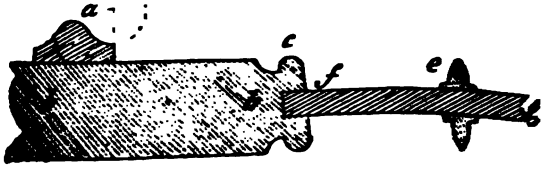


Fig. 27.

ction to the line 1 2. Enlarged elevation [illegible] on r of moulding b b, or b″, is given at the two diagrams to the right at bottom of drawing. Another method of forming the junction is shown at the middle diagram at the foot of Fig. 25, the shaded part [illegible] rm of tenon with the ends of moulding [illegible]

A FOUR-PANELLED DOOR.

In Fg. 28 I give a drawing—to a scale of ⅛, or 1½ inch to the foot—of a four-panelled interior or room

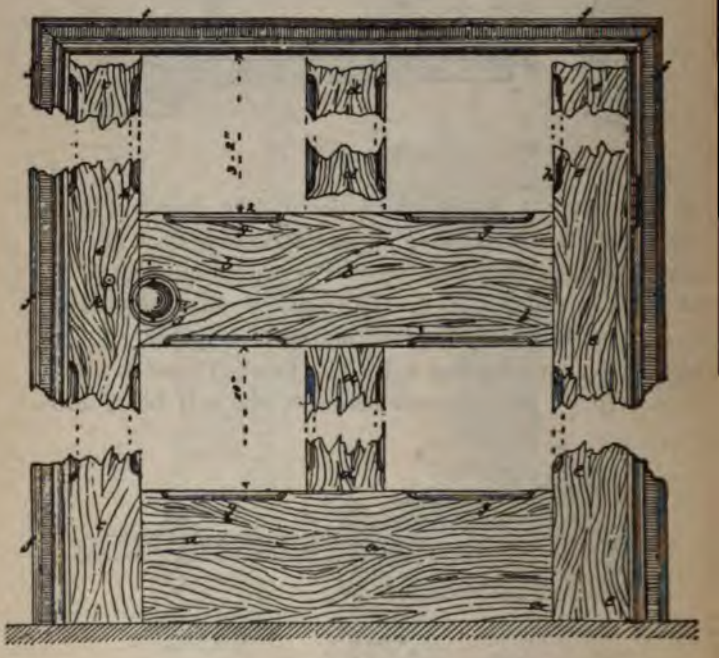


Fig. 28.

door, showing all the leading parts of the framework, with the exception of top rail, which is usually about half the breadth or depth of the middle of lock rail, marked b b in the drawing. The panels are not shown,

but the dimensions of the spaces they occupy are given. The panels are plan "square," the only ornamentation in this example being a "stop chamfer" worked on the margin of stiles, and rails, as shown at g g and h h. In the drawing a a is the "bottom rail," b b the middle, or usually "lock rail," as it carries the "mortise lock," the handle of which is shown at j. The "key hole" is covered by a movable part, hung or jointed at upper end, called the "escutcheon," or more frequently in technical talk, the "scutcheon," or "skutcheon," shown at k. The stiles are at c c, e e—the stiles c c, termed the "lock stile," being that in which the lock is mortised. The stile e e is called the "hanging stile," being that on which the door is "hinged" or "hung" to the door casing. The vertical pieces, or "muntins," which divide the panels from each other, placing them in pairs on each side of the door, are shown at d d. The door framing thus constructed is surrounded on both sides and at top by the architraves f f f.

ARCHITRAVES OF A FOUR-PANELLED DOOR.

The section of architrave in relation to the door casing or check is in upper diagram to the left in Fig. 29, a a being part of the door casing, b b the section of architrave, of which part elevation is shown at c c, 1, 2, 3, and 4 showing similar parts in section correspondingly lettered. The edge view of the "lock stile" as a a f in the figure preceding, is shown at d d; e e shows the brass plate let into the edge and secured by screw nails as shown. This is part of the lock furniture of the door, f indicating position and section of the shooting or locking bolt of the lock, which passes into the aperture of a brass plate secured to the inner side or edge of the door casing. The bolt, which secures the door, being closed —not locked—f being the locking bolt, is shown at g, this being worked by the handle j of the lock. The part of the lock furniture attached to the door casing opposite to the edge, as d d d, of the door stile, is shown in the lower diagram to the right. The part 3 3 in this corresponds to the face of the recessed or rebated part p in drawing above, cut in the face of the door casing n n n, the door passing into and resting against the face of recess or rebate p. In the upper diagram to the right, o o o is the outer architrave secured to the door casing n n n, r part of the inner architrave. The part of the lock furniture secured to the door casing is shown at t t; it is a brass plate let into the face g, or 3 3 of recess or rebate p. The aperture in this into which the bolt f of the lock passes is shown at p; that into which the bolt

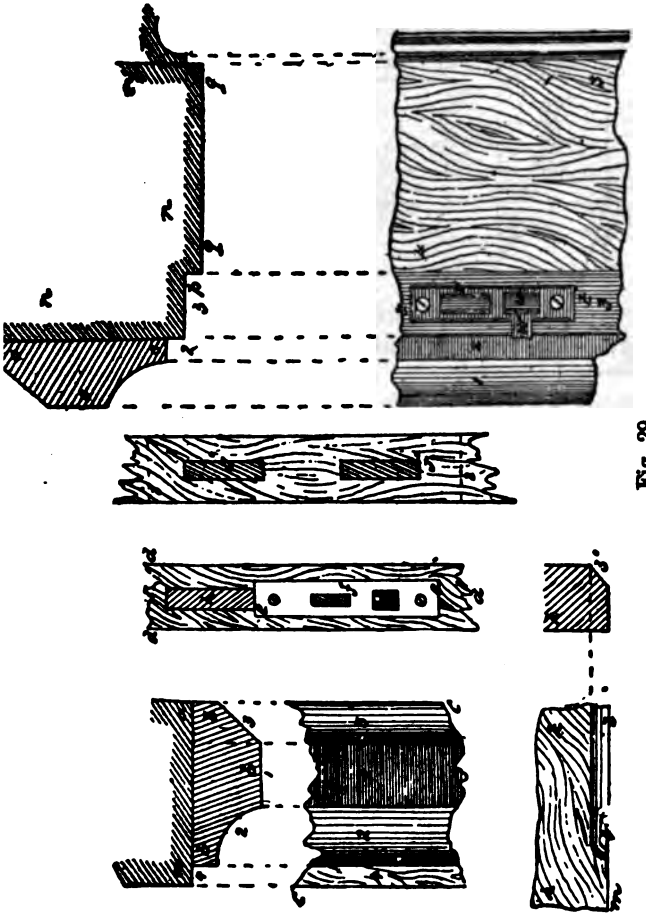


Fig. 29.

moved by the hand passes is at u, a spring w, cast onto the plate t t, being shown at w. A small projecting part

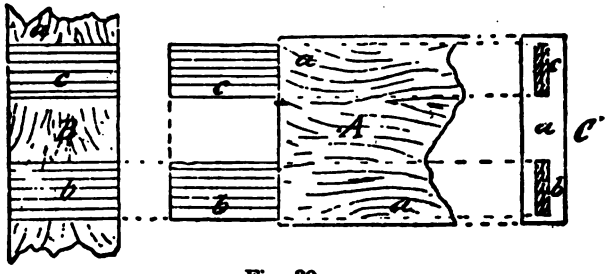


Fig. 30.

as w′, to make the opening and closing of the door more easy. The two diagrams to the left at lower part of

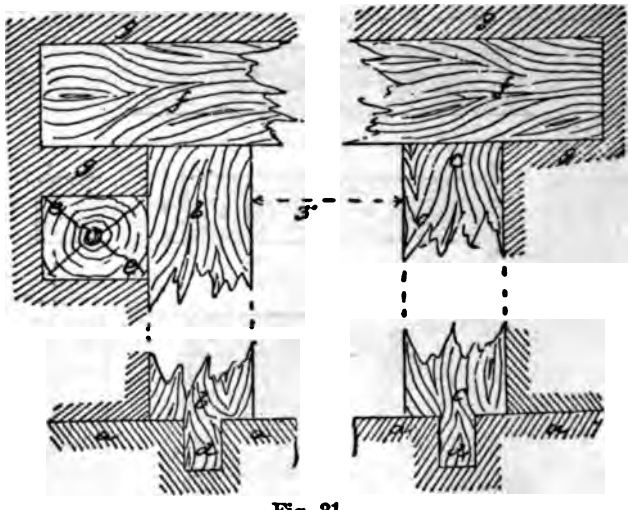


Fig. 31.

drawing show the elevation k l m, the chamfered part of framing with section at k′ k′.

SOME EXAMPLES OF ORNAMENTAL WOOD-WORK.

The following examples are introduced in order to

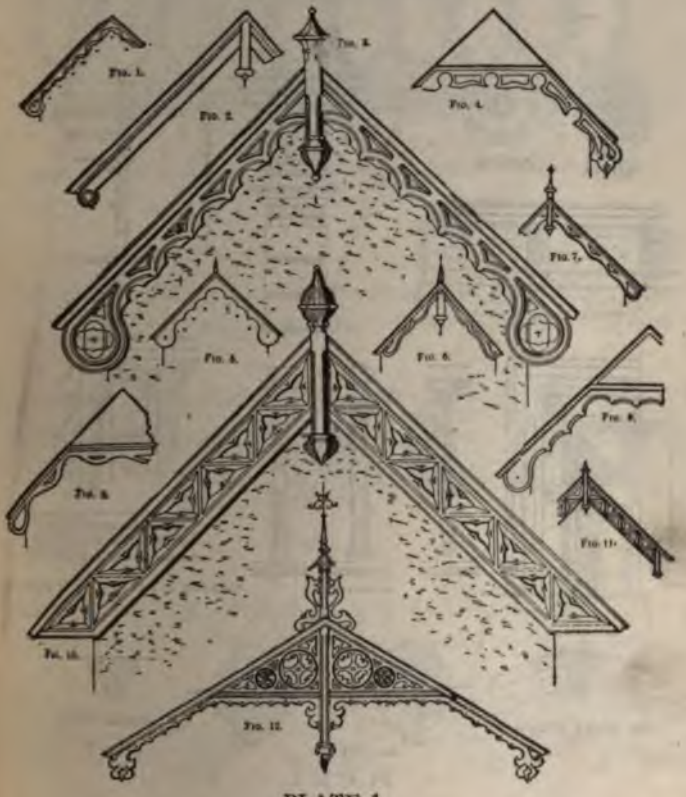


PLATE 1.

give the workman an idea of the shape and construction of low-cost ornamental wood-work. The figures

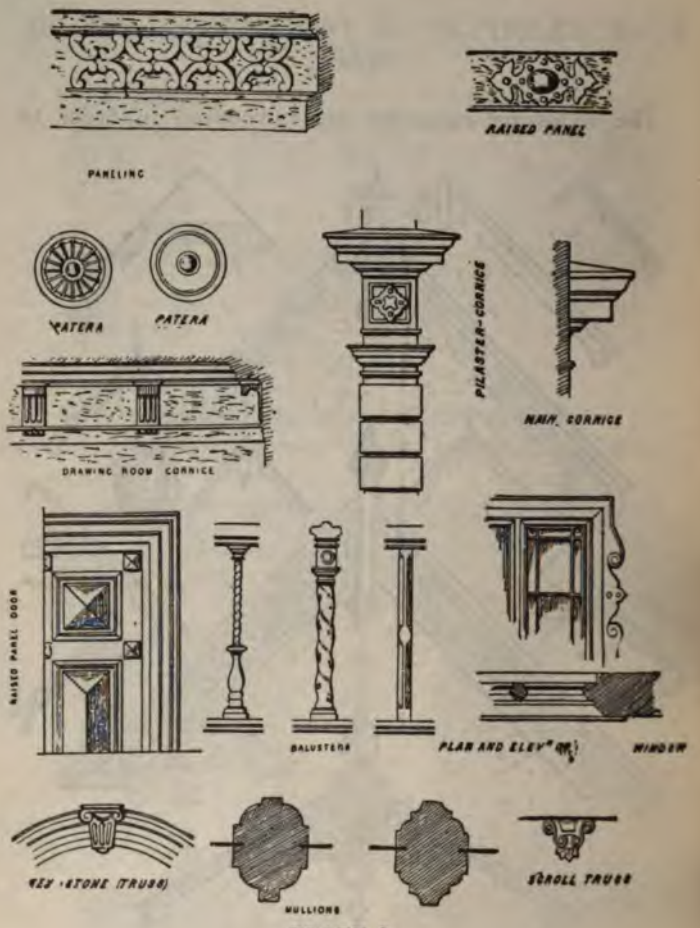


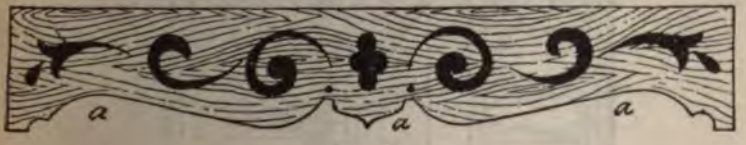
PLATE 2.

shown from No. 1 to No. 12, inclusive, exhibit a number of large boards, chiefly in Gothic style. Plate No. 2 is a style which was in vogue very much a few years ago

and was generally known among carpenters as Ginger-Bread work. It is well adapted for sea-side cottages or

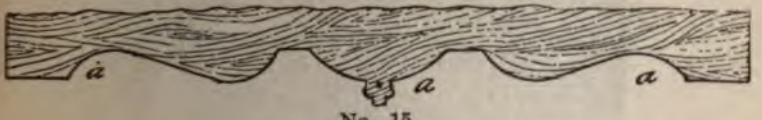
No. 13.

summer residences; it consists mostly of cutwork. Nos. 2, 5, 8 and 9 are well adapted for ordinary cottage



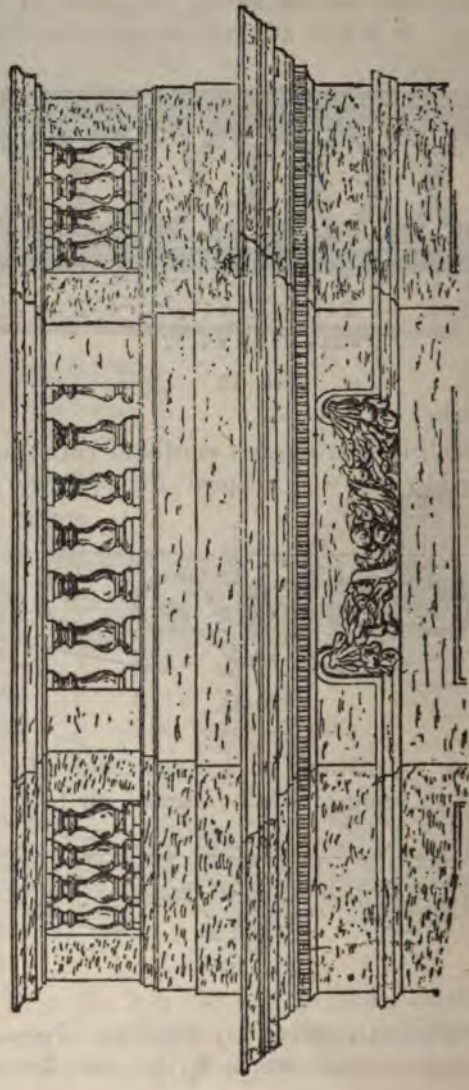
No. 14.

work. Nos. 13, 16 and 21 are well suited for balustrades, No. 16 being especially adapted for heavy balus-



No. 15.

trades on verandas or over bay windows. Nos. 14, 15 and 17 require no explanation, as they may be adapted

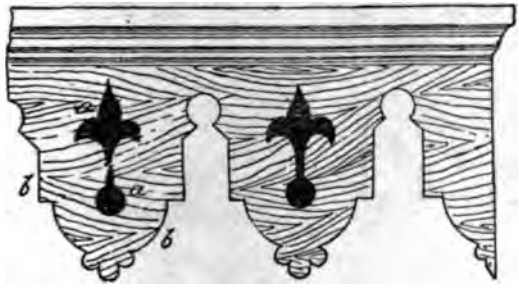


No. 16.

to a thousand different purposes. Nos. 18 and 19 make very handsome drops for verandas and other similar

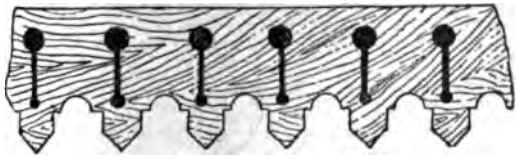
No. 17.

work. No. 29 shows a single drop with the grain of the wood running vertically. A number of these placed



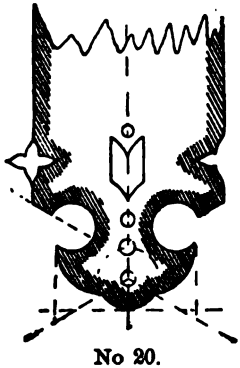
No. 18.

together edge to edge make a very nice trimming for verandas. No. 22 shows a cut bracket which will often

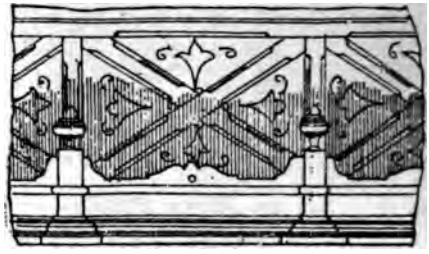


No. 19.

be found useful. No. 23 shows an elaborate railing suitable for a veranda or balcony. No. 24 exhibits a



No 20.



No. 21.

No. 22.

No. 23.

No. 24.

No. 25.

perforated panel suitable for many places. No. 26 shows a portion of a circular panel which may be perforated or the ornaments may be planted on, according to exigencies. See Plates. The balance of the examples shown speak for themselves. They offer a number of excellent suggestions to the progressive workman. These examples will doubtless prove of great value to the workman.

QUESTIONS ON MODERN CARPENTRY
VOL. I.

The student will be expected to read carefully these papers before doing any work. His name and address will require to be given on each page. He will be expected to write up the questions in a neat and intelligent manner, using his own language and style, representing the answers in such a manner as will be intelligible. Make all drawings as clear as possible, and whenever it can be done render them in India ink. Let each answer be original, do not copy either from the instruction paper nor from any other source. The paper used may be of any kind, provided that it is clean and durable. Do not attempt an answer until you have thoroughly grasped the subject.

QUESTIONS.

1. Give definition of a "circle."
2. What term is given to a line that is drawn through center to circumference of a circle?
3. What term is given to a line drawn from center to circumference of a circle?
4. What term is given to a line (less than the diameter) that cuts the circumference of a circle at two points?
5. Give definition of a "tangent."
6. Give definition of a "segment of a circle."
7. Give sketch of a circle showing the "diameter," "radius," "chord," "segment" and "tangent."

8. Give sketch and describe how to find the center of a circle.

9. Into how many equal parts is the measurement of the circumference of a circle divided?

10. Give the three terms used in measurement of the circumference of a circle, and show how they are written.

11. What is a quadrant of a circle?

12. How many degrees are in a quadrant of a circle?

13. How many degrees are in a semi-circle?

14. What term is given to the angle of a circle that is half of a right angle?

15. Give sketch and describe how three right angles may be formed within a semi-circle.

16. Give sketch and describe how a hexagon may be formed within a circle.

17. Give sketch of a hexagon showing how an equilateral triangle may be formed.

18. Give sketch and describe how a right angle or quadrant may be bisected.

19. Give sketch and describe how to get a straight line that shall equal the circumference of a circle or part of a circle or quadrant.

20. Give sketch and show how quadrant may be divided into any number of equal parts, say thirteen.

21. Give sketch and show how equilateral triangle may be employed in forming the trefoil.

22. Give sketch and describe method of finding the "stretch out" or length of circumference of a circle.

23. Give rule by arithmetic of how to find the circumference of a circle.

24. Give sketch and describe how a curve having

any reasonable radius, may be obtained, if but three points in the circumference are available.

25. Give a practical illustration of how to find a place to locate a center, where the diameter is great.

26. What is a "polygon?"

27. Give the names applied to polygons having three sides, four sides, five sides, six sides, seven sides, eight sides, nine sides, ten side, eleven sides, and twelve sides respectively.

28. Give the two names under which polygons are classified.

29. Give sketch showing how a trigon may be constructed and how the miter joint may be obtained.

30. Give sketch and describe how a square may be formed.

31. Give sketch and describe how to construct a pentagon.

32. Give sketch and describe how a hexagon may be formed.

33. Give sketch and describe how a heptagon may be formed.

34. Give sketch and describe how an octagon may be formed.

35. Show practically how all regular octagons may be constructed.

36. Give a practical illustration of how a perpendicular line may be made on any given straight line.

37. Give a practical illustration of how to bisect an angle by the aid of the steel square alone.

38. Give a practical illustration of how to bisect an acute angle by same method—steel square.

39. Show practically how to get a correct miter cut, or angle of 45° on a board.

40. Show how to construct a figure showing an angle of 30° on one side, and on the other an angle of 60°.

41. Show how the diameter of a circle may be obtained through the aid of the steel square.

42. Show how an equilateral triangle may be obtained through use of the steel square.

43. Show how to describe an octagon by using the steel square.

44. Show how a near approximation of the circumference of a circle may be obtained by use of the steel square and a straight line.

45. Give illustration how a board may be divided into any given number of equal parts by aid of steel square or pocket rule.

46. Give the definition of an "ellipse."

47. Give an illustration of one of the simplest methods of describing an ellipse.

48. Give an illustration of projecting an ellipse by using a trammel.

49. Give illustration of describing an ellipse by the intersection of lines.

50. Give illustration of describing an ellipse by the intersection of arcs.

51. Show how radial lines may be obtained for arches and elliptical work.

52. Give an illustration how to describe a diamond or lozenge-shaped figure.

53. Give illustration how to describe a spiral or scroll by a simple method.

54. Give illustration of how a spiral may be described in a scientific manner, and which can be formed to dimension.

55. Give illustration of the method of obtaining a spiral by arcs of circles.

56. Give illustration and method of forming a "parabola."

57. Give illustration and method of forming an "hyperbola."

58. Give the names of the different kinds of arches in buildings.

59. Mention the names given to pointed arches.

60. What is the name given to the stones forming an arch?

61. What is the name given to the centre stone in an arch?

62. Give the names applied to the various divisions of an arch, namely, the highest point, the lowest point, and the spaces between respectively.

63. What is the name given to the under or concave surface of an arch?

64. What is the name given to the upper or convex surface of an arch?

65. What are the names given to the supports of an arch?

66. Show by illustration and describe how to obtain the curves and radiating lines of a semi-circular arch.

67. Show by illustration and describe how to obtain the curves and radiating lines of a segment arch.

68. Show by illustration and describe two examples of Moorish or Saracenic arches, one of which is pointed.

69. What is a "flatband"?

70. Give illustration and describe how to obtain the curves and radiating lines of the elliptic arch.

71. Give illustration and describe how the centers and curves of an equilateral arch may be obtained.

72. Give illustration and describe how the centers and curves of a lancet arch may be obtained.

73. Give illustration and describe how the center and curves of a low or drop arch may be obtained.

74. Give illustration and describe how the centers and curves of a Gothic arch with a still less height, may be obtained.

75. Give illustration and describe another four-centered arch of less height.

76. Give illustration and describe how to obtain an equilateral Ogee arch.

77. Give illustration and describe method of obtaining the lines for an Ogee arch, having a height equal to half the span.

78. Give some instances in carpenter work where half of the Ogee curve is employed.

79. Give a description of the steel square and its several divisions.

80. Give a practical illustration of how a board or scantling may be measured by use of steel square.

81. Give rule how to find hypothenuse of a right-angled triangle.

82. Give an illustration of how length of braces may be obtained by use of the square.

83. Describe the use of the "octagonal scale" on the tongue of the square.

84. Show method how the pitch of a roof may be obtained by use of the square.

85. Show method to obtain bevels and lengths of hip rafters by use of the square.

86. Show method for finding the length and cuts for cross-bridging.

87. Show method for obtaining the "cuts" for octagon and hexagon joints.

88. Show by illustration the method of defining the pitches of roofs, and giving the figures on the square for laying out the rafters for such pitches.

89. Give a short description of what is known as balloon framing, and how the different parts are constructed.

90. Give illustration and describe a "hip-roof."

91. Give illustration and describe a "lean-to-roof."

92. Give illustration and describe a "saddle-roof."

93. Give illustration and describe a "mansard roof."

94. Give illustration and describe a simple hip-roof having a ridge.

95. Give illustration and describe an "octagon roof."

96. Give illustration and describe manner of construction of a "dome roof."

97. Give illustration and rules for construction of an octagonal spire.

98. Give a few illustrations of scarfing timbers.

99. Show a few examples of strengthening and trussing joints, girders and timbers.

100. Explain what is meant by the term "kerfing."

101. Give illustration showing how to determine the number and distances apart of saw kerfs required to bend a board round a corner.

102. Give illustration of how to make a "kerf" for bending round an ellipse.

103. Describe how to bend thick stuff around work that is on a rake.

104. Give illustration and describe how to lay out a hip rafter for a veranda having a curved roof.

105. Give illustration and describe how to obtain

the curve of a hip rafter, when the common rafters have an ogee or concave and convex shape.

106. Give illustration and describe how raking mouldings are used to work in level mouldings.

107. Describe the kind of mouldings called "spring mouldings."

108. Give illustrations showing plan and elevation of cluster column of wood for 4 columns and describe how constructed.

109. Give illustration of a hopper and describe how to be constructed.

110. Give illustration and describe how a conical tower roof may be curved.

111. Give illustration and describe how to cover a dome roof.

112. Give illustration and describe how the semi-circular soffit of a doorway may be made.

113. Describe how a circle soffit may be laid off into panels.

114. Give illustration and describe method for obtaining correct shape of a veneer for a gothic-splayed window or door head.

115. Give illustrations and describe two methods of dovetailing hoppers, trays and other splayed work.

116. Give description of how an ordinary straight flight of stairs may be constructed.

117. Give sketch showing part of a straight stair.

118. Give sketch showing stair with winders and landing.

119. Give sketch and describe a stair with brackets.

120. Give sketch showing stair with two newels and balusters, also paneled string and spandrel.

121. Give sketches of seven of the latest designs for doors.

122. Give five sketches showing methods of constructing and finishing a window frame for weighted sash.

123. Give sketches showing the various parts of a bay window for a balloon frame.

124. Give illustration and describe six examples of shingling roofs.

125. Show by sketch how panels are formed.

126. Describe the various kinds of panels named.

127. Make sketch of a four-panel door.

128. How are air-tight cases made? Describe the method of making.

129. What is meant by the word "stile"?

130. What is a rail in a door? What is a muntin?

131. What is a chamfer? Describe one.

132. Examine examples of sketches of ornamental wood-work, draw and describe a "baye-board."

133. Make a design of perforated insular panel.

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MODERN CARPENTRY

VOLUME II.

PREFACE

In a previous volume—Modern Carpentry—I made a fairly successful attempt to put together a series of plain and simple examples of working problems and their solution suited to the capacity of all ordinary mechanics, and owing to the fact that many thousands of that volume have found their way into the hands of carpenters and joiners in the United States, Mexico and Canada, and to the other fact that the author, as well as the publishers, have received hundreds of letters asking for something more on the same lines, of a higher grade, it has been determined to make another or more volumes, on the same subject, hence "Modern Carpentry and Joinery" advanced course.

In the present work I have drawn largely from acknowledged authorities and from workmen of recognized ability to which have been added the results of my own experience and observation and my knowledge of the kinks and secrets of the woodworking trades. In a work of this kind the reader must expect to find something he has met in other places, and perhaps in other adaptations, but I think that upon careful analysis he will find the presentation of the cases somewhat improved, and rendered in a more simple and understandable manner. The selections, too, I think will be found more suitable and more appropriate to the present-day practice than most of the matter found in recent technical literature on the subject. At any rate,

It has been my endeavor in the formation of the present volume to place in a handy form, instructive examples of the better class of work of the carpenters and joiners' "Art."

It is not intended to repeat what has already been published in the first volume of Modern Carpentry, unless such repetition will be necessary to explain or formulate some similar matter.

Young men are apt to think that because they have a fair knowledge of their trades, they know all that is required and if they peruse the first volume of this work, and have mastered its contents, they have reached the limit. This, of course, is a great mistake, as will readily be discovered by a glance over the matter of the present volume, and I can say right here, and now, that even the present volume does not by any means cover the whole subject, for, at least a half dozen other volumes could be written without touching on the other two already in the market, and the subject would not nearly be exhausted.

It is not necessary for me to quote the authorities from whom I have drawn, unless the matter is of such importance as to demand special recognition. I may say however that in very few books written during the last few years on the subject of carpentry, there has [illegible] presented that had not been published [illegible] other, but the description [illegible] all—have been [illegible] the present book does not [illegible] those that have pre- [illegible] and more [illegible]

It must also be understood, that while this book goes out to the public under my name as author, I do not claim authorship, for really, it is more of a compilation than an original work, but, I do claim that the selections and compilations made are better and more suited to the wants of the present-day workman than can be found in any other similar work published in this or any other country.

FRED T. HODGSON,
Editor and Compiler.

Collingwood,

PREFACE TO SECOND EDITION.

MODERN CARPENTRY.

(ADVANCED SERIES.)

VOL. II.

A preface is an introduction or "foreword" to a new book or a new discourse, but in this case, it is a second introduction to a well-known book which has recently had very important improvements and annexes added to the original work; and the author finds it difficult to say much of the main work other than was said in the preface sent out in the first edition of this volume; and the recent additions are hardly bulky enough to warrant a lengthy introduction, as they may be taken as being in the same class as the general contents of the work, which is good, practical, instructive, up-to-date and equal, if not superior, to anything of the kind offered to American workmen. The most reliable indication of the merits of a book of this kind, is the opinions of the practical men who buy such books for profitable use; and the thousands of flattering letters that have been received by the author and publishers these few years bear the strongest testimony of the sterling value of the first edition. To give extracts from these letters would take up as much space as the contents of the volume requires, so that cannot be attempted, and may not be necessary, but, I may be pardoned for offering a few,

which may perhaps prove as effective as a thousand would:

"I am well pleased with your book, Vol. 2, Modern Carpentry. It is the best thing I ever saw of the kind, and has helped me wonderfully." LOUIS DUPREY, Winnipeg, Man.

"We use five of your books in our Trade Teaching Department, and find 'Modern Carpentry' the most useful we have. We make it a text-book." REV. J. B. GAUTHEIR, Iberville College, Iberville, Quebec.

"'Modern Carpentry,' second volume, arrived some time ago, and I found in it just what I wanted, and this repays me more than ten fold the cost." JOHN WILKS, Minneapolis, Minn.

"Your book, 'Modern Carpentry,' second volume, is a dandy. I have got a lot of good things out of it. I would not take $100.00 for it if I could not buy another. Good luck to you." JAMES E. WEEKS, San Francisco, Cal.

As before stated, I could fill a volume with similar extracts, but my modesty forbids me from giving more unasked.

This is my preface to this second volume of the new edition of "Modern Carpentry." It is like a "Donkey's Gallop," short and sweet, but somewhat "wobbly."

FRED T. HODGSON.

Collingwood, Ont.

PART I.

SOLID GEOMETRY.

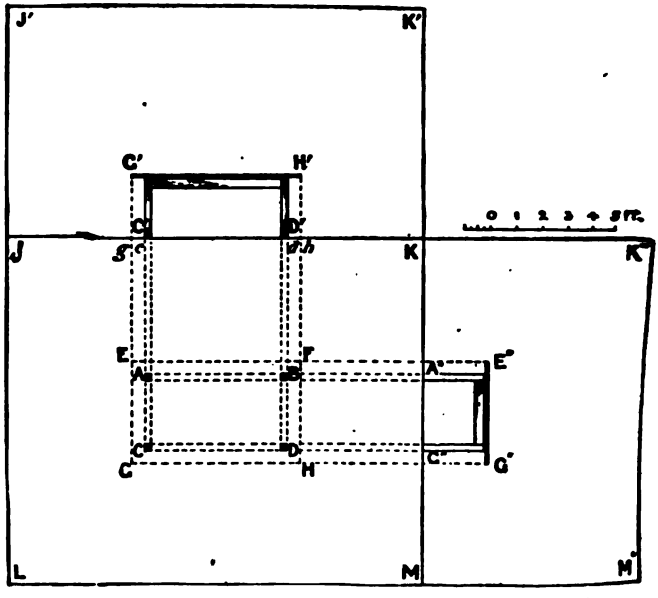
INTRODUCTORY.

In the first volume of Modern Carpentry I gave a short treatise on plain or Carpenters' Geometry, which I trust the student has mastered, and thus prepared himself for a higher grade in the same science, namely, **Solid Geometry**: and to this end, the following treatise has been selected, as being the most simple and the most thorough available.

Solid geometry is that branch of geometry which treats of solids—i.e., objects of three dimensions (length, breadth and thickness). By means of solid geometry these objects can be represented on a plane surface, such as a sheet of paper, in such a manner that the dimensions of the object can be accurately measured from the drawing by means of a rule or scale. The "geometrical" drawings supplied by the architect or engineer for the builder's use are, with few exceptions, problems in solid geometry, and therefore a certain amount of knowledge of the subject is indispensable, not only to the draughtsman who prepares the drawings, but also to the builder or workman who has to interpret them.

As the geometrical representations of objects consist entirely of lines and points, it follows that if projections of lines and points can be accurately drawn,

the representation of objects will present no further difficulty. A study of lines and points, however, is somewhat confusing, unless the theory of projection has first been grasped, and for this reason the subject will be introduced by a simple concrete example,



Vertical Projections (or Elevations) and Horizontal Projection (or Plan) of a Table in the Middle of an Oblong Room

Fig. 1.

such, as a table standing in the middle of a room. The four legs rest on the floor at A, B, C, and D (Fig. 1), and the perpendiculars let fall from the corners of the table-top to meet the floor at E, F, G, and H. The oblong E F G H represents the horizontal projection or "plan" of the table-top; the small squares at A,

B, C, and D represent the plan of the four legs, and the lines correcting them represent the plan of the frame work under the top. The large oblong J K L M is a plan of the room.

The plan or horizontal projection of an object is therefore a representation of its horizontal dimensions —in other words, it is the appearance which an object presents when every point in it is viewed from a position vertically above that point.

In a similar manner an elevation or vertical projection of an object is a representation of its vertical dimensions, and also, it should be added, of some of its horizontal dimensions,—i. e., it is the appearance which an object presents when every point in it is viewed from a position exactly level with that point, all the lines of sight being parallel both horizontally and vertically. Thus, the front elevation of the table (or the vertical projection of the side G H) will be as shown at G′ H′ C′ D′, and the vertical projection of the side J K of the room will be J K J K. The vertical projection of the end of E G of the table will be as shown E″ G″ A″ C″ and of the end K M of the room will be K″ M″ K M; the drawing must be turned until the line K M is horizontal, for these and projections to be properly seen.

By applying the scale to the plan, we find that the length of the table-top is six and a half feet, the breadth 4 feet, and the distance of the table from each wall 4¾ feet. From the **front elevation** we can learn the height of the table, and also give its length and distance from the end walls of the room. From the **end elevation** we can ascertain the breadth of the table and

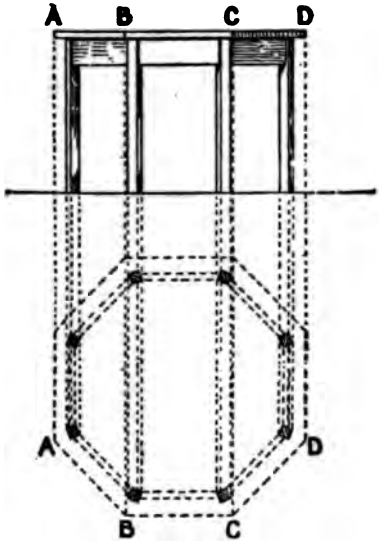
its distance from the sides of the room, as well as its height.

To make the drawing clearer, let us imagine that the walls of the room are of wood and hinged at the level of the floor. On the wall J K draw the front elevation of the table and then turn the wall back on its hinges until it is horizontal,—i. e., in the same plane as the floor. Proceed in a similar manner with the end K M, and we get the three projections of the room and table on one plane, as shown in the diagram. To avoid confusion the end elevation will not be further considered at the present.

It will be seen that the line J K represents the angle formed by the wall and floor,—in other words, it represents the intersection of the vertical and horizontal "planes of projection," it is known as "the line of intersection," or "the ground line." If a line is let fall from G′ perpendicular to J K, the two lines will meet at G, and they will be in the same straight line. Similarly, the perpendiculars H′ h and h H are in the same straight line. Lines of this kind perpendicular to the planes of projections are known as "projectors" and are either horizontal or vertical G′ g and H′ h are vertical projectors; G g, C c, D d, and H h are horizontal projectors.

Vertical projectors are not always parallel to one of the sides of the object represented, or, if parallel to one side, are not parallel to other sides which must be represented; thus, a vertical projector or "elevation" of an octagonal object, if parallel to one of the sides of the octagon, must be oblique to the two adjacent sides. In Fig. 2 an octagonal table is shown. The

plan must first be drawn, and from the principal points of the plan projectors must be drawn perpendicular to the vertical plane of the projection, until they cut the ground line, and from this perpendiculars must be erected to the height of the several parts of



Plan and Elevation of an Octagonal Table

Fig. 2.

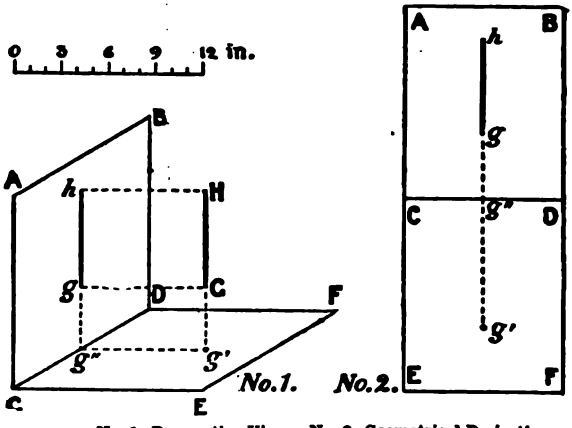
the table. The elevation can then be completed without difficulty. The side B C of the table is parallel to the vertical plane of projection, but the adjacent sides A B and C D are oblique.*

*A distinction must be made between "perpendicular" and "vertical." The former means, in geometry, a line or plane at right angles to another line or plane, whether these are horizontal, vertical or inclined; whereas a vertical line or plane is always at right angles to a horizontal line or plane. The spirit-level gives the horizontal line or plane, the plumb-rule gives the vertical.

2. POINTS, LINES, AND PLANES.

I. To determine the position and length of a given straight line, parallel to one of the planes of the projection.

Let G H (Fig. 3) be the given straight line. To determine its position (i e., in regard to horizontal and vertical planes), it is only necessary to determine the position of any two of the extreme points.



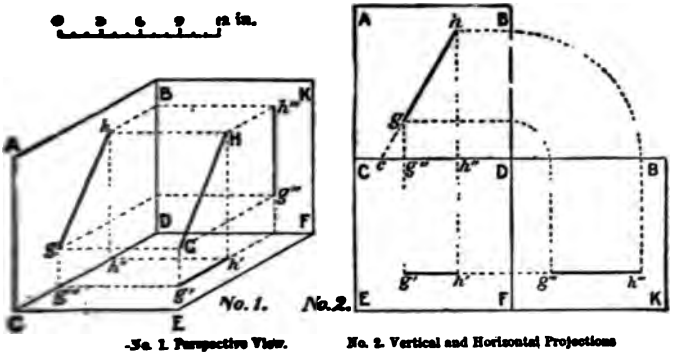
No. 1. Perspective View. No. 2. Geometrical Projections Horizontal and Vertical

Fig. 3.

Let A B C D be a vertical plane parallel to the given line, and C D E F a horizontal plane. The vertical projection or elevation of the line is represented by the line h g, and the horizontal projection or plan by the point g', the various projections being shown by dotted lines. The given line is proved to be vertical, because

its horizontal projection is a point; its length as measured by the scale, is 6 inches; its height (g g″) above the line of intersection C D is 4 inches; and its horizontal distance (g′ g″) from the same line is 8 inches.

If the illustrations are turned so that C D E F become a vertical plane, and A B C D the horizontal plane then G H will be horizontal line, because one of its vertical projections is a point. Other vertical projections of the line can be made,—as, for example, a side elevation,—in which the projection will appear as a line and not a point, but a line must be horizontal if any vertical projection of it is a point.



No. 1. Perspective View. No. 2. Vertical and Horizontal Projections

Fig. 4.

Let the given line G H (Fig. 4) be parallel to the vertical plane, but inclined to the horizontal plane. Then g h will be a vertical projection, and g′ h′ its horizontal projection or plan. By producing h g till it cuts C D at c, it will be found that the given line is inclined at an angle of 60° to the horizontal plane; its length, as measured by the scale along the vertical

projection g h, is 8 inches; the height of G above the horizontal plane (measured at g g″) is 3 inches, and the height of H (measured at h h″) is 9¾ inches.

II. To determine the length of a given straight line which is oblique to both planes of projection.

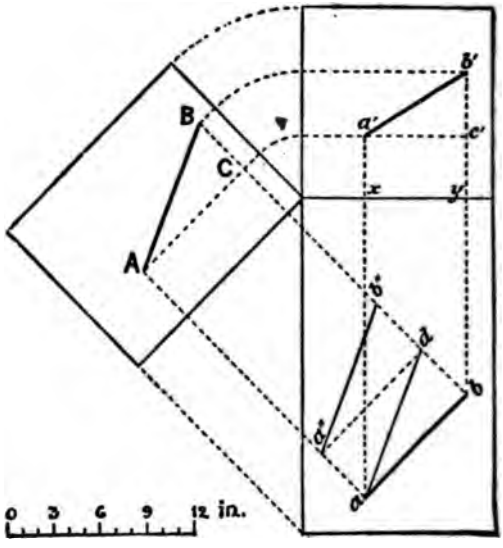
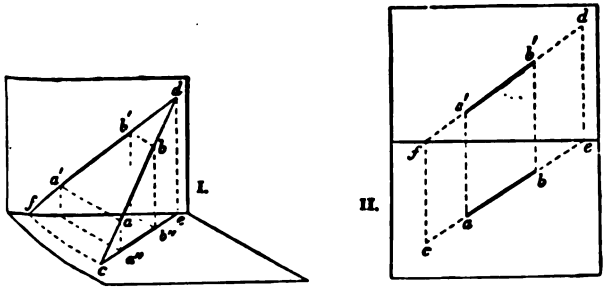


Fig. 5.

Let a b (Fig. 5) be the horizontal projection and a′ b′ the given vertical projection of the given line. Draw the projection A B on a plane parallel to a b in the manner shown. From this projection the length of the given line will be found (by applying the scale) to be 10 inches. The height C B is of course equal to the height c′ b′, and the horizontal measurement A C is equal to the horizontal projection a b, and the angle

A C B is a right angle. It follows therefore that, if from b the line b d is drawn perpendicular to a b and equal to the height $c' b'_2$ the line joining a d will be the length of the given line. To avoid drawing the horizontal line a' c' the height of a' and b' above x y are usually set up from a and b as at a'' and b'', the line a'' b'' is the length of the given line.*

III. The projections of a right line being given, to find the points wherein the prolongation of that line would meet the planes of projection.



I. Perspective View. II. Vertical and Horizontal Projections

Fig. 6.

Let a b and a' b' (Fig. 6, II) be the given projection of the line A B. In the perspective representation of the problem it is seen that A B, if prolonged, cuts the horizontal plane in c, and the vertical plane in d, and the projections of the prolongation become c e and f d. Hence, if a b, a' b' (Fig. 6, II) be the projections

*The application of this problem to hips is obvious. Suppose that *a b* is the plan of a hip-rafter, and *a' b'* an elevation, the length of the rafter will be equal to *a d* or A B.

of A B, the solution of the problem is obtained by producing these lines to meet the common intersection of the planes in f and e, and on these points raising the perpendiculars f c and e d, meeting a b produced in c and a′ b′ produced in d; c and d are the points sought.*

IV. If two lines intersect each other in space, to find from their given projections the angles which they make with each other.

Let a b, c d, and a′ b′ c′ d′ (Fig.7) be the projections of the lines. Draw the projectors e′ f′ f′ e′, perpendicular to the line of intersection a′ c′, and produce it indefinitely towards E″; from e draw indefinitely, e E′ perpendicular to the line e′ f, and make e E′ equal to f″ e, and draw f E′. From f as a centre describe the arc E″ g E″, meeting e f produced in E″, and join a E″ c E″. The angle a E″ c is the angle sought. This problem is little more than a development of problem II. If we consider e f, e′f′, as the horizontal and vertical projections of an imaginary line lying in the same plane as a e and c e, we find the length of this line by problem II to be f E′; in other words f E′ is the true altitude of the triangle a e c, a′ e′ c′. Construct a triangle on the base a e with an altitude f E′ equal to f E′, and the problem is solved. The practical application of this problem will

*The points *d* and *c* are known respectively as the vertical and horizontal "traces" of the line A B, the trace, of a straight line on a plane being the point in which the straight line, produced if necessary, meets or intersects the plane. A horizontal line cannot therefore have a horizontal trace, as it cannot possibly, even if produced, meet or intersect the horizontal plane; for a similar reason, a vertical line cannot have a vertical trace.

e understood if we imagine a e c to be the plan and
'e' c' the elevation of a hipped roof; f E' gives us the
ngth and slope of the longest common rafter or spar,
nd E" c is a true representation of the whole hip, i.
, on a plane parallel to the slope of the top. It will

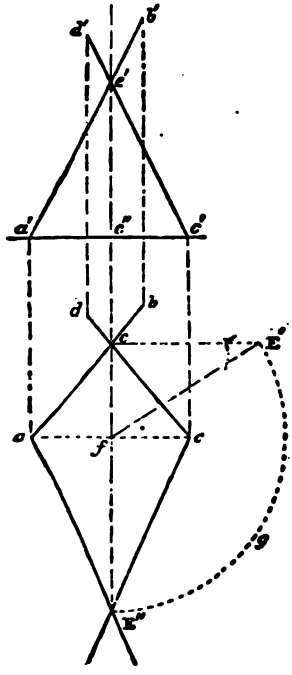
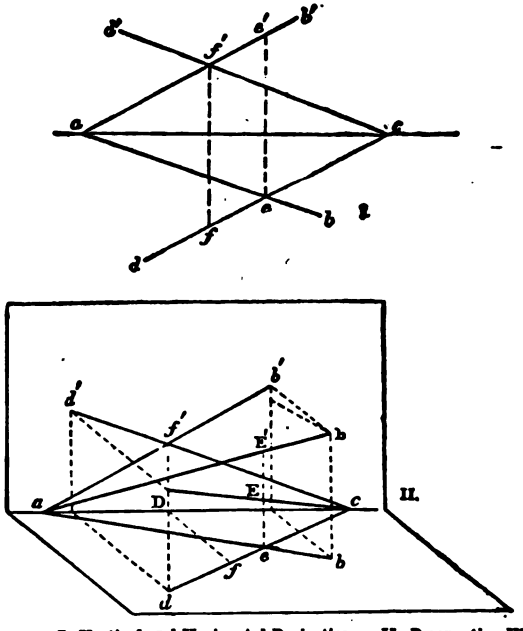


Fig. 7.

observed that the two projections (e and e') of the
nt of intersection of the two lines are in a right
perpendicular to the line of intersection of the
nes of projection. Hence this corollary.—The pro-

jections of the point of intersections of two lines wi cut each other in space are in the same right line pendicular to the common intersection of the pl of projection. This is further illustrated by the problem.



I. Vertical and Horizontal Projections. II. Perspective View

Fig. 8.

V. To determine from the projection of two l which intersect each other in the projections, whe the lines cut each other in space or not.

Let a b, c d, a b′, c d′ (Fig. 8, I) be the project of the lines. It might be supposed, as their project

intersect each other that the lines themselves intersect each other in space, but on applying the corollary of the preceding problem, it is found that the intersections are not in the same perpendicular to the line of intersection a c of the planes of projection. This is represented in perspective in Fig. 8, II. We there see that the original lines a B c D do not cut each other, although their projections a b, c d, a b′, c d′, do so. From the point of intersection e raise a perpendicular to the horizontal plane, and it will cut the original line c D, in E, and this point therefore belongs to the line c D, but c belongs equally to a B. As the perpendicular raised on e passes through E on the line c D, and through E on the line a B, these points E E′ cannot be the intersection of the two lines, since they do not touch; and it is also the same in regard to f f. Hence, when two right lines do not cut each other in space, the intersections of their projections are not in the same right line perpendicular to the common intersection of the planes of projection.

VI. To find the angle made by a plane with the horizontal plane of projection.

Let a b and a c, Fig. 9, be the horizontal and vertical traces of the given plane, i. e., the lines on which the given plane would, if produced, cut the horizontal and vertical planes of projection. Take any convenient point d in a b, and from it draw d e perpendicular to a b, and cutting the line of intersection x y in e, from e draw e d perpendicular to x y and cutting a c in d′. The angle made by the given plane with the horizontal plane of projection is such that, with a base d e, it has a vertical height e d′. Draw such an

angle on the vertical plane of projection by setting off from e the distance e d″ equal to e d, and joining d′ d″. The angle d′ d″ e is the angle required.*

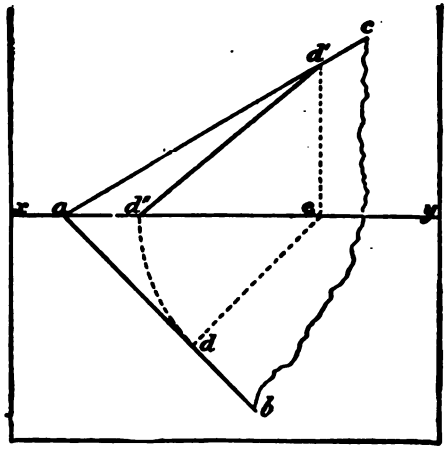


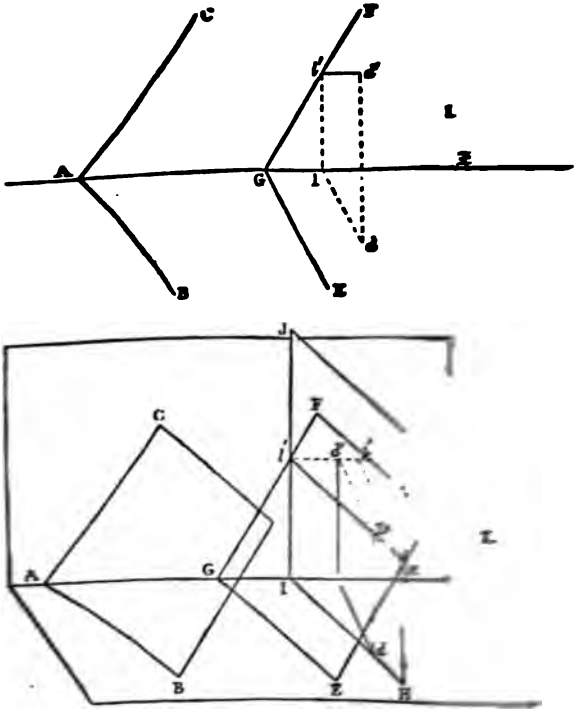
Fig. 9.

VII. The traces of a plane and the projections of a point being given, to draw through the point a plane parallel to the given plane.

In the perspective representation (Figs. 10 and 11) suppose the problem solved, and let B C be the given

*The angle made by a plane with the vertical plane of projection can be found in a similar manner. If we imagine the part above *x y* in Fig. 9 to be the horizontal projection and the part below *x y* to be the vertical projection—in other words, if Fig. 9 is turned upside down—*a b* becomes the vertical trace and *a c* the horizontal trace, and the angle *d′ d″ e* is the angle made by the given plane with the vertical plane of projection.

ne. and A C. A B its vertical and horizontal traces,
E F a plane parallel to the given plane, and G F,
its traces. Through any point D, taken at pleasure



I. Vertical and Horizontal Projections. II. Perspective View

Fig. 10.

n the plane E F, draw the vertical plane
orizontal trace of which, I H, is parallel
he plane H J cuts the plane E F in the line
s vertical trace G F in I'. The horizontal

of k′ l′ is H I, and its vertical projection k′ l′ ; and as the point D is in k l′, its horizontal and vertical projections will be .. and d′. Therefore, if through d be traced a line .. l, parallel to A B, that line will be the horizontal projection of a vertical plane passing through the original point D; and if an l be drawn the indefinite perpendicular L″ l′, and through d′, the vertical projection of the given point, be drawn the horizontal line d′ l′, cutting the perpendicular in l′, then the line F G drawn through l parallel to A C, will be the vertical trace of the plane required; and

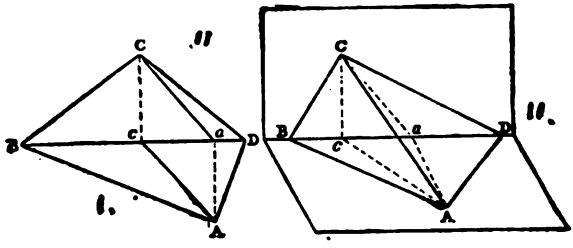


Fig. 11.

the line G E drawn parallel to A B, its horizontal trace. Hence, **all planes parallel to each other have their projections parallel, and reciprocally.** In solving the problem, let A B, A C (Figs. 10, I) be the traces of the given plane, and d d the projections of the given point. Through d draw d l parallel to A B, and from I draw I l′ perpendicular to A H. Join d d′ and through d′ draw d′ l′ parallel to the line of intersection A H. Then F l′ G drawn parallel to A C, and G E parallel to A B, are the traces of the required plane.

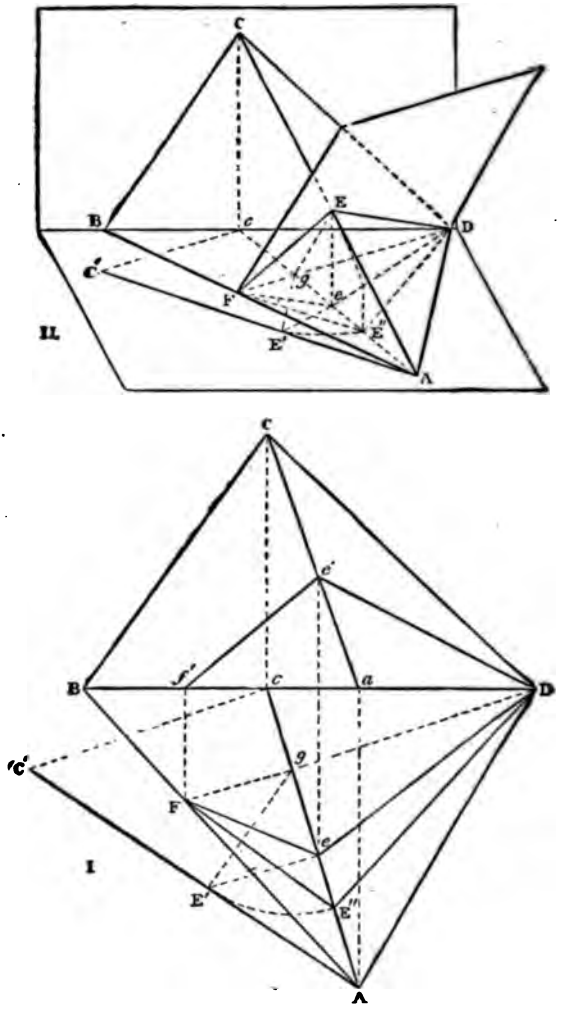
VIII. The traces A B, B C, and A D, D C, of two planes which cut each other being given, to find the projections of their intersections.

The planes intersect each other in the straight line A C (Fig.II, 11), of which the points A and C are the traces, since in these points this line intersects the planes of projection. To find these projections, it is only necessary to let fall on the line of intersection in Fig. II, 1, the perpendiculars A a, C c, from the points A and C, and join A c, C a. A c will be the horizontal projection, and C a the vertical projection of C A, which is the line of intersection or arris of the planes.

IX. The traces of two intersecting planes being given, to find the angle which the planes make between them.

The angle formed by two planes is measured by that of two lines drawn from the same point in their intersection (one along each of the planes), perpendicular to the line formed by the intersection. This will be better understood by drawing a straight line across the crease in a double sheet of note-paper at right angles to the crease; if the two leaves of the paper are then partly closed so as to form an angle, we have an angle formed by two planes, and this angle is the same as that formed by two lines which have been drawn perpendicular to the line of intersection of the two planes. These lines in effect determine a third plane perpendicular to the arris. If, therefore, the two planes are cut by a third plane at right angles to their intersection the solution of the problem is obtained.

On the arris A C (Fig. 12, 11) take at pleasure any

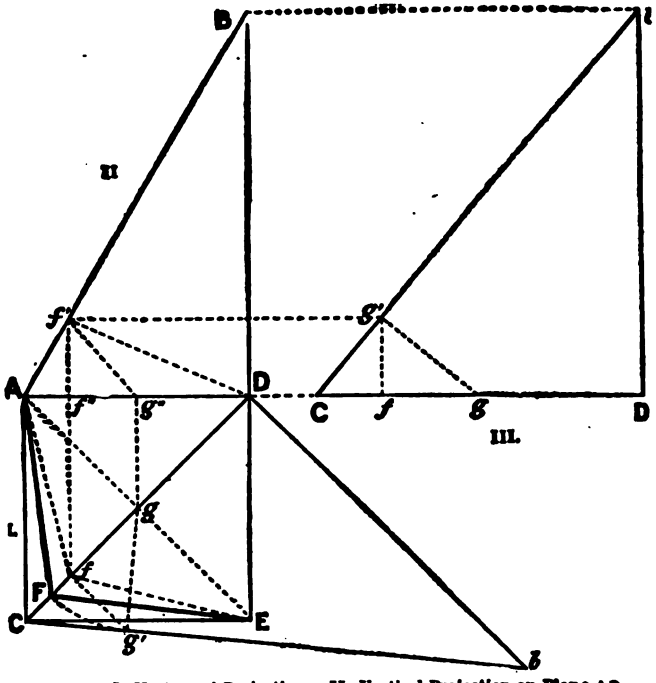


I. Vertical and Horizontal Projections. II. Perspective View
Fig. 12.

E, and suppose a plane passing through that cutting the two given planes perpendicular to rris. There results from the section a triangle , inclined to the horizontal plane, and the angle ich, D E F, is the measure of the inclination of vo planes. The horizontal projection of that tri- is the triangle D e F, the base of which, F D, is ndicular to A c (the horizontal projection of the A C), and cuts it in the point g, and the line E perpendicular to D F. The line g E is necessary ndicular to the arris A C, as it is in the plane , and its horizontal projection is g e. Now, sup- the triangle D E F turned on D F as an axis, and horizontally, its summit will then be at E″, and ' F is the angle sought. The perpendicular g E so in the vertical triangle A C c, of which the is the hypothenuse and the sides A c, C C are projections. This description introduces the so- n of the problem.

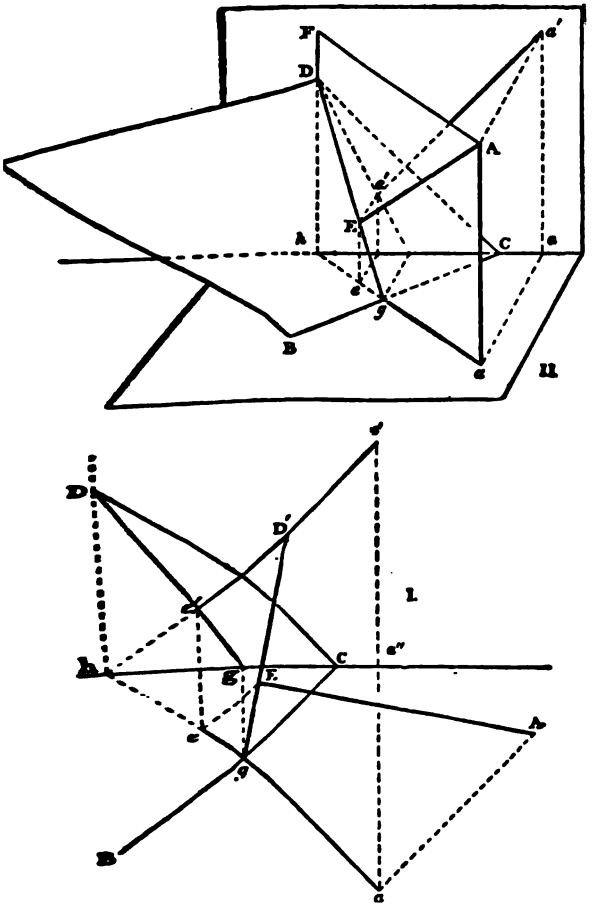
rough any point g (Fig. 12, 1) on the line A c, horizontal projection of the arris or line of inter- on of the two planes, draw F D perpendicular to ; on A c (which for the moment must be consid- as a "line of intersection" or "ground line" for cond vertical projection) describe the vertical pro- ion of the arris by drawing the perpendicular and then joining A C′. A C gives the true length inclination of the arris. From g draw g E′ per- dicular to A C′, and meeting it in E′; from E′ let a perpendicular E e′ or A c, meeting A c in e. D is the horizontal projection of the triangle F) (see No. 11) and from this the vertical projection

f′ e′ D can be drawn as shown. We have now obtained the vertical and horizontal projections of two intersecting lines, namely, F e, e D, and f′ e′, e′ D, and by problem (4) the triangle which they make with each other can be found. It will be seen that g E′ is the



I. Horizontal Projection. II. Vertical Projection on Plane A B.
III. Vertical Projection on Plane C D.
Fig. 13.

true altitude of the triangle f′ e′ D, as c E is equal to e′ e. Set off therefore from g towards A a distance g E equal to g E, and join F E, E″ D; F E″ D is the angle made by the two intersecting planes.



I. Vertical and Horizontal Projections. II. Perspective View

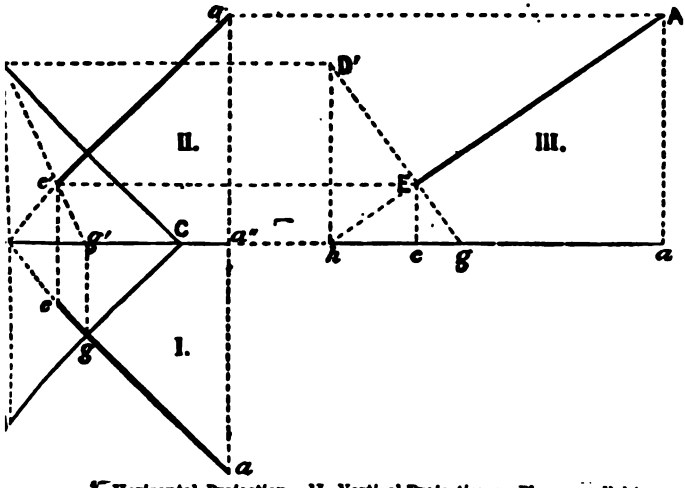
Fig. 14.

X. Through a given point to draw a perpendicular to a given plane.

Let a and a′ (Fig. 14, II.) be the projections of the given point, and B C, C D the horizontal and vertical traces of the given plane. Suppose the problem solved, and that A E is the perpendicular drawn through the A to the plane B D, and that its intersection with the plane is the point E. Suppose also a vertical plane a F to pass through A E′, this plane would cut B D in the line g D, and its horizontal trace a h would be perpendicular to the trace B C. In the same way a′ e′, the vertical projection of A E, would be perpendicular to C D, the vertical trace of the plane B D. Thus we find that if a line a h is drawn from a, perpendicular to B C, it will be the horizontal trace of the plane in which lies the required perpendicular A E, and h F will be the vertical trace of the same plane. From a′, draw upon C D an indefinite perpendicular, and that line will contain the vertical projection of A E, as a h contains its horizontal projection. To find the point of intersection of the line A E with the given plane, construct the vertical projection g D of the line of intersection of the two planes, and the point of intersection of that line with the right line drawn through a′, will be the point sought. If from that point a perpendicular is let fall on a h, the point e will be the horizontal projection of the point of intersection E.

In Fig. 15, 1, let B C, C D be the traces of the given plane, and a, a′ the projections of the given point. From the point a, draw a h perpendicular to B C; a h will be the horizontal projection of a plane passing

ertically through a, and cutting the given plane. n a h as "ground line" draw a vertical projection s follows: From a, draw a A perpendicular to a g, nd make it equal to a″ a′; from h draw h D′ per- endicular to h a, and make h D′ equal to h D; draw ; D, which will be the section of the given plane by



I. Horizontal Projection. II. Vertical Projection on Plane parallel to A a″. III. Vertical Projection on Plane parallel to A a

Fig. 15.

ı vertical D g, and the angle h g D′ will be the meas- ıre of the inclination of the given plane with the hor- zontal plane; there is now to be drawn, perpendicu- ar to this line, a line A E through A, which will be he vertical projection on a h of the line required. rom the point of intersection E let fall upon a h a

perpendicular, which will give e as the horizontal projection of E. Therefore a e is the horizontal projection of the required perpendicular, and a′ e′ its vertical projection on the original "ground line" h a″. It follows from this problem that—**Where a right line in space is perpendicular to a plane, the projections of that line are respectively perpendicular to the traces of the plane.**

XI. Through a given point to draw a plane perpendicular to a given right line.

Let a, a′ (Fig. 16, 1) be the projections of the given point A, and b c, b′ c′ the projections of the given line B C.

The foregoing problem has shown that the traces of the plane sought must be perpendicular to the projections of the line, and the solution of the problem consists in making to pass through A, a vertical plane A f (Fig. 16, 11), the horizontal projection of which will be perpendicular to b c.

Through a (Fig. 16, 1) draw the projection a f perpendicular to b c. From f raise upon K L the indefinite perpendicular f f, which will be the vertical trace of the plane a f f perpendicular to the horizontal plane, and passing through the original point A (in No. 11). Then draw through a in the vertical projection a horizontal line, cutting f f in f, which point should be in the trace of the plane sought; and as that plane must be perpendicular to the vertical projection of the given right line draw through f a perpendicular to b c, and produce it to cut K L in G. This point G is in the horizontal trace of the plane sought. All that remains therefore, is from G to draw

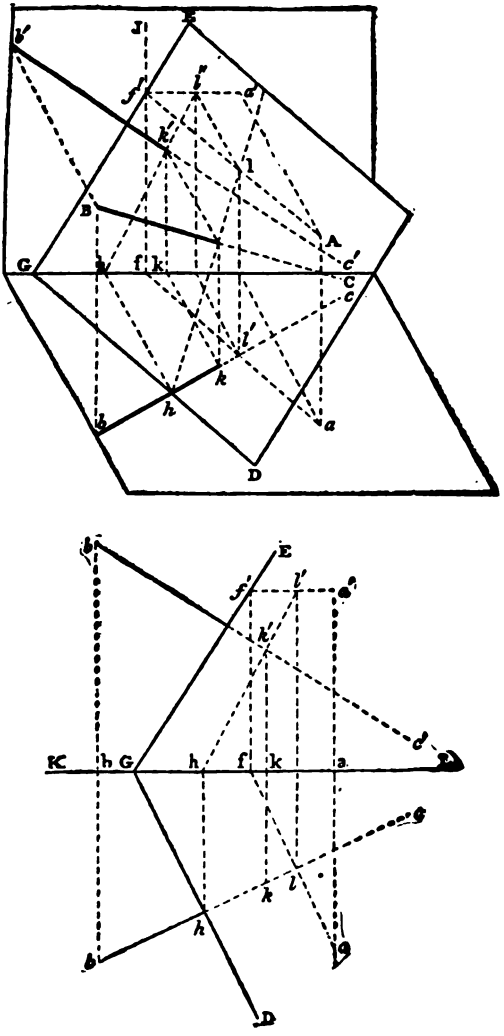


Fig. 16.

G D perpendicular to b c. If the projections of the straight line are required, proceed as in the previous problem, and as shown by the dotted lines; the plane will cut the given line at k in the horizontal projection, and at k in the vertical projection.*

XII. A right line being given in projection, and also the traces of a given plane, to find the angle which the line makes with the plane.

Let A B (Fig. 17, 11) be the original right line intersecting the plane C E in the point B. If a vertical plane a B pass through the right line, it will cut the plane C E in the line f B, and the horizontal plane in the line a b. As the plane a B is in this case parallel to the vertical plane of projection, its projection on that plane will be a quadrilateral figure a b of the same dimensions, and f B contained in the rectangle will have for its vertical projection a right line D b, which will be equal and similar to f B. Hence the two angles a b D, A B f, being equal, will equally be the measure of the angle of inclination of the right

*The diagram will be less confusing if the projection on *a h* is drawn separately, as in Fig. 16, where I is the horizontal projection or plan, II the vertical projection or elevation on a plane parallel to *h a''*, and III the vertical projection or elevation on a plane parallel to *h a*. To draw No. III draw first the ground-line *h a* equal to *h a* on No. I, and mark on it the point *g*; from *h* draw the vertical *h* D' equal to *h* D, and from *a* draw the vertical *a* A equal to *a''* *a'*; join D' *g* and A *h*, and from the point of intersection E let fall a perpendicular on *h a*, cutting it in e. A E is the actual length and inclination of the required line, and *a e* its horizontal length. Transfer the length *a e* to No. I, and from *e* draw *e e'* perpendicular to *h a''* and cutting *a' h* in *e'*. If the drawing has been correctly made, a line from E parallel to the ground-line *h a''* will also intersect *a' h* in *e'*.

line A B to the plane C E. Thus the angle a b D (Fig. 17, 1), is the angle sought.

This case presents no difficulty; but when the line is in a plane which is not parallel to the plane of

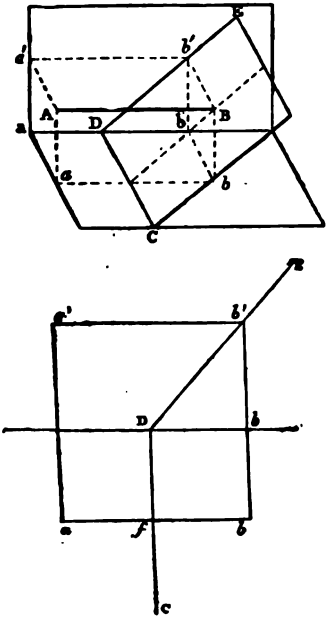


Fig. 17.

projection, the problem is more difficult; as, however, the second case is not of much practical value, it will not be considered.

3. STRAIGHT-SIDED SOLIDS.

XIII. Given the horizontal projection of a regular tetrahedron, to find its vertical projection.

Let A B C d (Fig. 18) be the given projection of the tetrahedron, which has one of its faces coincident with the ground-line. From d draw an indefinite line

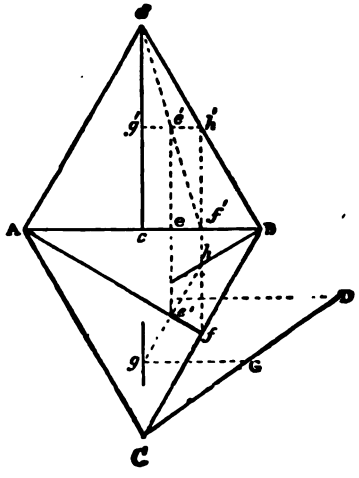


Fig. 18.

d D perpendicular to d C, and make C D equal to C B, C A. or A B; d D will be the height sought, which is carried to the vertical projection from c to d. Join A d and B d, and the vertical projection is complete. This problem might be solved in other ways.

XIV. A point being given in one of the projections of a tetrahedron, to find the point on the other projection.

Let e be the point given in the horizontal projection (Fig. 18). It may be considered as situated in the plane C B d, which is inclined to the horizontal plane, and of which the vertical projection is the triangle c B d. According to the general method, the vertical projection of the given point is to be found somewhere in a perpendicular raised on its horizontal projection e. If through d and the point e be drawn a line produced to the base of the triangle in f, the point e will be on that line, and its vertical projection will be on the vertical projection of that line f e d, at the intersection of it with the perpendicular raised on e. If through e be drawn a straight line g h, parallel to C B, this will be a horizontal line, whose extremity h will be on B d. The vertical projection of d B is d B; therefore, by raising on h a perpendicular to A B, there will be obtained h, the extremity of a horizontal line represented by h g in the horizontal plane. If through h is drawn a horizontal line h g this line will cut the vertical line raised on e in e, the point sought. If the point had been given in g on the arris c d, the projection could not be found in the first manner; but it could be found in the second manner, by drawing through g, a line parallel to C B, and prolonging the horizontal line drawn through h, to the arris c d, which it would cut in g, the point sought. The point can also be found by laying down the right-angled triangle C d D (which is the development of the triangle formed by the horizontal pro-

jection of the arris C d, the height of the solid, and the length of the arris as a hypotenuse), and by drawing through g the line g G perpendicular to C d, to intersect the hypotenuse in G, and carrying the height g G from c to g in the vertical projection. One or other of these means can be employed according to circumstances. If the point had been given in the vertical instead of the horizontal projection, the same operations inverted would require to be used.

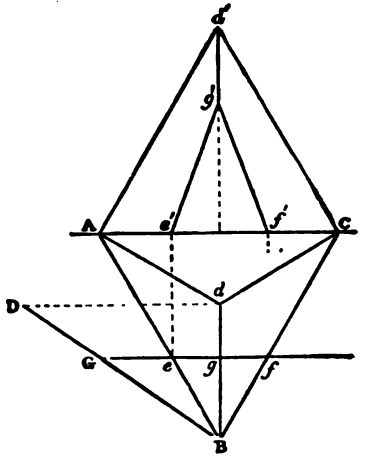


Fig. 19.

XV. Given a tetrahedron, and the trace of a plane (perpendicular to one of the planes of projection) cutting it, by which it is truncated, to find the projection of the section.

First when the intersecting plane is perpendicular to the horizontal plane (Fig. 19), the plane cuts the

base in two points e f, of which the vertical projections are e and f; and the arris B d is cut in g, the vertical projection of which can readily be found in any of the ways detailed in the last problem. Having found g join e g f g and the triangle e g f is the projection of the intersection sought.

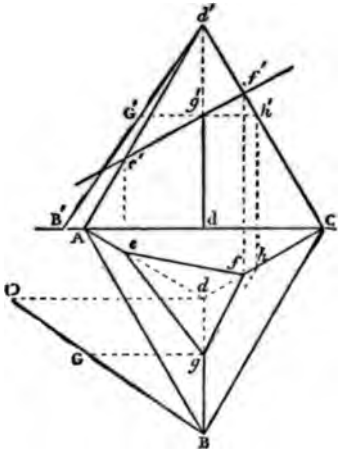


Fig. 20.

When the intersecting plane is perpendicular to the vertical plane, as e f in Fig. 20, the horizontal projections of the three points e g f have to be found. The point g in this case may be obtained in several ways. First by drawing G g h through g, then through h drawing a perpendicular to the base, produced to the arris at h, in the horizontal projection, and then drawing h g parallel to C B, cutting the arris B d in g, which is the point required. Second, on d B, the hor-

izontal projection of the arris, construct a triangle d D B, d B being the altitude of the tetrahedron, and B D the arris, and transfer this triangle to the vertical projection at d d B. From g draw the horizontal line cutting B d in G; g G is the horizontal distance of the required point in the arris, from the vertical axis of the tetrahedron as d is horizontal projection of the vertical axis, and d B the horizontal projection of the arris, it follows that the length gG, transferred to d g, will give the required point g. The points e and f are found by drawing lines from e and f perpendicular to the ground-line, and producing them till they meet the horizontal projections of the arrises in e and f. The triangle e f g is the horizontal projection of the section made by the plane e f.

XVI. The projections of a tetrahedron being given, to find its projections when inclined to the horizontal plane in any degree.

Let A B C d (Fig. 21) be the horizontal projection of a tetrahedron, with one of its sides coincident with the horizontal plane, and e d B its vertical projection; it is required to find its projections when turned round the arris A B as an axis. The base of the pyramid being a horizontal plane, its vertical projection is the right line c B. If this line is raised to c by turning on B, the horizontal projection will be A c2 B. When the point c, by the raising of B c, describes the arc c c, the point d will have moved to d, and the perpendicular let fall from that point on the horizontal plane will give d3, the horizontal projection of the extremity of the arris C d; for as the summit d moves in the same plane as C, parallel to the vertical plane

of projection the projection of the summit will evidently be in the prolongation of the arris C d, which is the horizontal projection or trace of that plane. The process therefore, is very simple and is as follows: Construct at the point B the angle required, c B c, and make the triangle c d B equal to c d B;

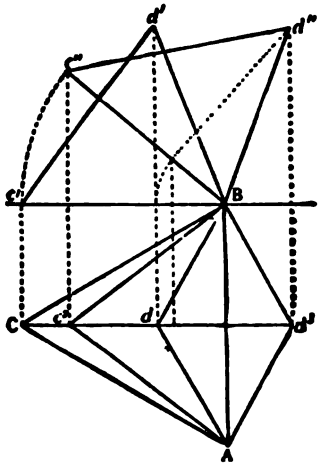


Fig. 21.

from d let fall a perpendicular cutting the prolongation of the arris C d in d3, and from c a perpendicular cutting the same line in c2; join B c2, A c2, B d3, A d3.

The following is a more general solution of the problem: Let A B C d (Fig. 22), be the horizontal projection of a pyramid resting with one of its sides on the horizontal plane, and let it be required to raise, by its angle C, the pyramid by turning around the arris A B, until its base makes with the horizontal

plane any required angle, as 50°. Conceive the right line C e turning round e, and still continuing to be perpendicular to A B, until it is raised to the required angle, as at e C. If a perpendicular be now let fall from C, it will give the point C as the horizontal projection of the angle C in its new position. Conceive

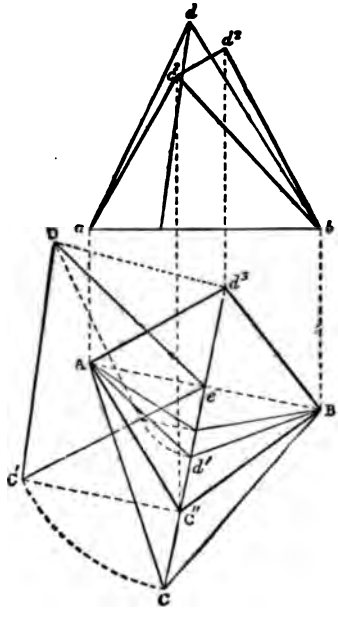


Fig. 22.

a vertical plane to pass through the line C e. This plane will necessarily contain the required angle. Suppose, now we lay this plane down in the horizontal projection thus: Draw from e the line e C, making

with e C an angle of 50°, and from e with the radius e c describe an arc cutting it in C. From C let fall on C e, a perpendicular on the point C, which will then be the horizontal projection of C in its raised position. On C e draw the profile of the tetrahedron C D e inclined to the horizontal plane. From D let fall a perpendicular on C e produced, and it will give d as the horizontal projection of the summit of the pyramid in its inclined position. Join A d, B d, A c, B c to complete the figure. The vertical projection of the tetrahedron in its original position is shown by a d b, and in its raised position by a, c2, d2, b, the points c2, and d2 being found by making the perpendiculars c3 c2 and d3 d2 equal to C C and d D respectively.

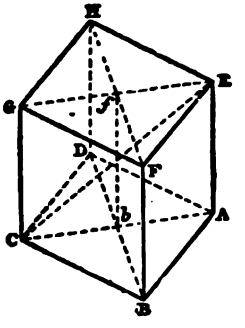


Fig. 23.

XVII. To construct vertical and horizontal projections of a cube, the axis 1 of which are perpendicular to the horizontal plane.

If an arris of the cube is given, it is easy to find its axis, as this is the hypotenuse of a right-angled triangle, the shortest side of which is the length of an

arris, and the longest the diagonal of a side. Conceive the cube cut by a vertical plane passing through its diagonals E G, A C (Fig. 23), the section will be the rectangle A E G C. Divide this into two equal right-angled triangles, by the diagonal E C. If in the upper and lower faces of the cube, we draw the diagonals F H, B D, they will cut the former diagonals in the points f and b. Now, as the lines b B, b D, f F, f H, are perpendicular to the rectangular plane A E G C, f b may be considered as the vertical projection of B F and D H, and from this consideration we may solve the problem.

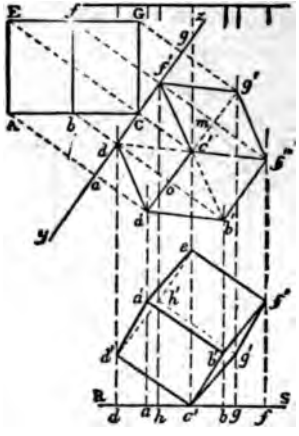


Fig. 24.

Let A E (Fig. 24) be the arris of any cube. The letters here refer to the same parts as those of the preceding diagram (Fig. 23). Through A draw an indefinite line, A C, perpendicular to A E. Set off on

his line, from A to C, the diagonal of the square of A E, and join E C, which is then the axis of the cube. Draw the lines E G, G G, parallel respectively to A C and A E, and the resulting rectangle, A E G C, is the section of a cube on the line of the diagonal of one of its faces. Divide the rectangle into two equal parts by the line b f, which is the vertical projection of the lines B F, D H (Fig. 23), and we obtain, in the figure thus completed, the vertical projection of the cube, as a c b d (Fig. 25).

Through C (Fig. 24), the extremity of the diagonal E C draw y z perpendicular to it, and let this line represent the common section or ground-line of the two planes of projection. Then let us find the horizontal projection of a cube of which A E G C is the vertical projection. In the vertical projection the axis E C is perpendicular to y z, and consequently, to the horizontal plane of projection, and we have the height above this plane of each of the points which terminate the angles. Let fall from each of these points perpendiculars to the horizontal plane, the projections of the points will be found on these perpendiculars. The horizontal projection of the axis E C will be a point on its prolongation, as c. This point might have been named e with equal correctness, as it is the horizontal projection of both the extremities of the axis, C and E. Through c draw a line parallel to y z, and find on it the projections of the points A and G, by continuing the perpendiculars A a, G g, to a and g. We have now to find the projections of the points b f (representing D B F H, Fig. 23,), which will be somewhere on the perpendiculars b b, f f, let fall

from them. We have seen in Fig. 23 that B F, D H are distant from b f by an extent equal half the diagonal of the square face of the cube. Set off, therefore, on the perpendiculars b b and f f, from o and m, the distance. A b in d, b, and f, f and join d a, a b, b f, f g, g f, to complete the hexagon which is the horizontal projection of the cube. Join f e, f e, and a c, to give the arrises of the upper half of the cube. The dotted lines d c, b c, g c, show the arrises of the lower side. Knowing the heights of the points in these vertical projections, it is easy to construct a vertical projection on any line whatever, as that on R S below.

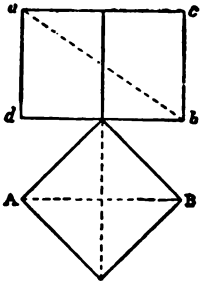


Fig. 25.

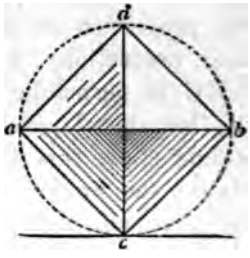


Fig. 26.

XVIII. To construct the projections of a regular octahedron, when one of its axis is perpendicular to either plane of projection.

Describe a circle (Fig. 26), and divide it into four equal parts by the diameters, and draw the lines a d, d b, b c, c a; a figure is produced which serves for either the vertical or the horizontal projection of the octahedron, when one of its axis is perpendicular to either plane.

XIX. One of the faces of an octahedron being given, coincident with the horizontal plane of projection, to construct the projections of the solid.

Let the triangle A B C (Fig. 27) be the given face. If A be considered to be the summit of one of the two pyramids which compose the solid, B C will be one of the sides of the square base, k C B i. The base makes with the horizontal plane an angle, which is easily found. Let fall from A a a perpendicular on B c, cutting it in d, with the length B c as a radius, and from

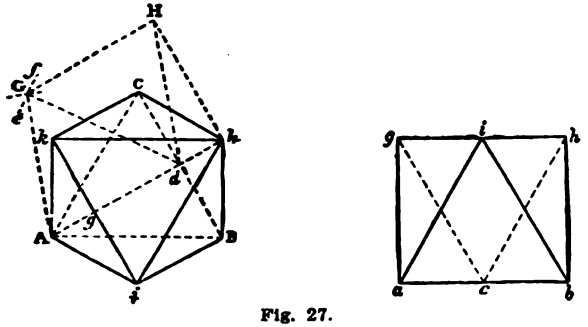


Fig. 27.

d as a centre, describe the indefinite arc e f. The perpendicular A d will be the height of each of the faces, and, consequently, of that which, turning on A, should meet the side of the base which has already turned on d. Make this height turn on A, describing from that point as a centre, with the radius A d, an indefinite arc, cutting the first arc in G, the point of meeting of one of the faces with the square base; draw the line G A, G d: the first is the profile or inclination of one of the faces on the given face A B C according to the angle d A G; the second, d G, is the inclination of the square base,

which separates the two pyramids in the angle A d G. The face adjacent to the side B C is found in the same manner. Through G, draw the horizontal line G H equal to the perpendicular A d. This line will be the profile of the superior face. Draw d H, which is the profile of the face adjacent to B C. From H let fall a perpendicular on A d produced, which gives the point h for the horizontal projection of H, or the summit of the superior triangle parallel to the first, draw h i parallel to C A, h k parallel to A B, A k and B h perpendicular to A B, and join k C, C h, B i, and A i and the horizontal projection is complete. From the heights we have thus obtained we can now draw the vertical projection shown in No. II, in which the parts have the same letters of reference.

The finding of the horizontal projection may be abridged by constructing a hexagon and inscribing in it the two triangles A C B, h i k.

XX. Given in the horizontal plane the projection of one of the faces of a dodecahedron, to construct its projections.

The dodecahedron is a twelve-sided solid, all the sides being regular and equal pentagons. It is necessary, in order to construct the projection, to discover the inclination of the faces among themselves. Let the pentagon A B C D E (Fig. 28) be the side on which the body is supposed to be seated on the plane. Conceive two other faces, E F G H D and D I K L C, also in the horizontal plane, and then raised by being turned on their bases, E D, D C. By their movement they will describe in space arcs of circles, which will terminate by the meeting of the sides D H, D I.

To find the inclination of these two faces.—From the points l and H let fall perpendiculars on their bases produced. If each of these pentagons were raised vertically on its base, the horizontal projection of H and l would be respectively in z z· but as both are raised

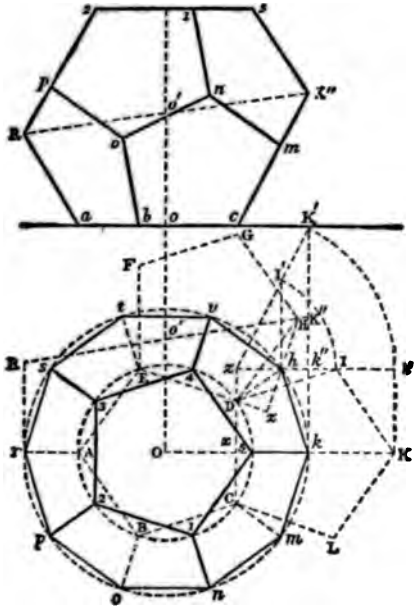


Fig. 28.

together, the angles H and I would meet in space above h where the perpendiculars intersect therefore, h will be the horizontal projection of the point of meeting of the angles. To find the horizontal projection of K, prolong indefinitely z I, and set off from z on z I the length xK in k; from z as centre with radius z I, describe

the arc II cutting the perpendicular h I in I; join z I; then from z as centre, with the radius z k, describe an arc cutting z I produced in the point K, from which let fall on z k a perpendicular K k, and produce it to k in x K. If, now, the right-angled triangle z k K, were raised on its base, k would be the projection of K. Conceive now the pentagon C D I K L turned round on C D, until it makes an angle equal to k z K with the horizontal plane, the summit K will then be raised above k by the height k K, and will have for its horizontal projection the point k. In completing the figure practically;—from the centre o, describe two concentric circles passing through points h D. Draw the lines h D, h k, and carry the last round the circumference in m n o p r s t u: through each of these lines draw radially the lines m C, o B, r A, t E, and these lines will be the arrises analogous to h D. This being done, the inferior half of the solid is projected. By reason of the regularity of the figure, it is easy to see that the six other faces will be similar in those already drawn, only that although the superior pentagon will have its angles on the same circumference as the inferior pentagon the angles of the one will be in the middle of the faces of the other. Therefore, to describe the superior half;—through the angles n p s v k, draw the radial lines n 1, p 2, s 3, v 4, k 5, and join them by the straight lines 1 2, 2 3, 3 4, 4 5, and 5 1.

To obtain the length of the axis of the solid, observe that the point k is elevated above the horizontal plane by the height k K: carry that height to k K: the point r, analogous to h, is raised the same height as that point, that is to say h i, which is to be carried from r

to R; and the line R K is the length sought. As this axis should pass through the centre of the body, if a vertical projection of the axis in O, and therefore O o is the half of the height of the solid vertically. By doubting this height, and drawing a horizontal line to cut the vertical lines of the angles of the superior face is obtained, as in the upper portion of (Fig. 28), in which the same letters refer to the same parts.

XXI. One of the faces of a dodecahedron being given, to construct the projections of the solid, so that its axis may be perpendicular to the horizontal plane.

Let A B E D C (Fig. 29, 1) be the given face. The solid angles of the dodecahedron are each formed by the meeting of three pentagonal planes. If there be conceived a plane B C passing through the extremities of the arrises of the solid angle A, the result of the section would be a triangular pyramid, the sides of whose base would be equal to one of the diagonals of the face, such as B C. An equilateral triangle b c f (Fig. 29, 11) will represent the base of that pyramid inverted, that is, with its summit resting on the horizontal projection, it it required to find the height of that pyramid, or which is the same thing, that one of the three points of its base b c f, for as they are all equally elevated, the height of one of them gives the others. There is necessarily a proportion between the triangle A b c (No. 11) and A B C (No. 1), since the first is the horizontal projection of the second. A g is the horizontal projection of A G; but A G is a part of A H, and the projection of that line is required for one of the faces of the solid; therefore as A G:A g::A H:x. In other words, the length, the length of x may be ob-

tained by drawing a fourth proportion of the three lines it will be found to be equal to A h; or it may be obtained graphically thus:—Raise on A g at g an indefinite perpendicular, take the length A G (No. 1) and carry it from A to G (No. 11); g is a point in the

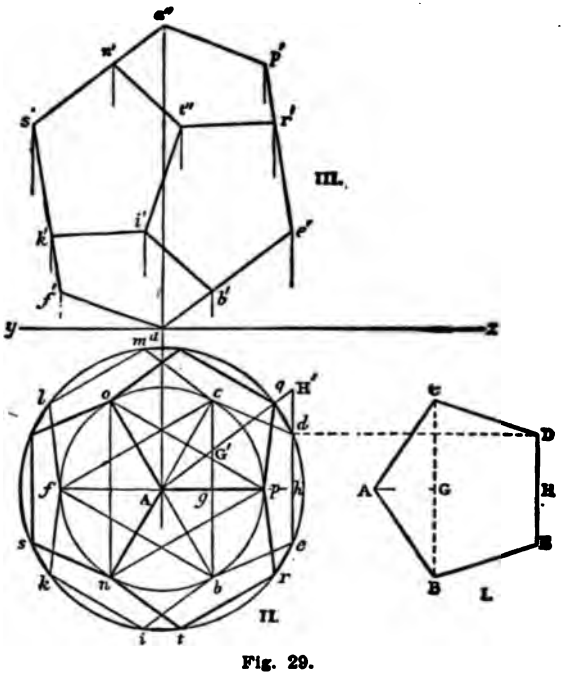


Fig. 29.

assumed pyramidal base b c f. Since A G is a portion of A H, A G will be so also. Produce A G, therefore, to H, making A H equal to A H (No. 1) and from H let fall a perpendicular on A g produced, which gives h the point sought. Produce H h, and carry on it the

length H D or H E from h to d and h to e; draw the lines c d, b e, and the horizontal projection of one of the faces is obtained inclined to the horizontal plane, in the angle H A h. As the other two inferior faces are similar to the one found, the three faces should be found on the circumference of a circle traced from A as centre, and with A d or A e as a radius. Join f A, prolong A n, A o, perpendicular to the sides of the triangle f c b, and make them equal to A h, and through their extremities draw perpendiculars, cutting the circumference in the points i k, l m. Draw the lines i b, k f, l f, m c, and the horizontal projections of the three inferior faces obtained. The superior pyramid is similar and equal to the inferior, and solely opposed by its angles. Describe a circle passing through the three points of the first triangle, and draw within it a second equilateral triangle n o p, of which the summits correspond to the middle of the faces of the former one. Each of these points will be the summit of a pentagon, as the points b c f. These pentagons have all their sides common, and it is only necessary therefore to determine one of these superior pentagons to have all the others. Six of the faces of the dodecahedron have now been projected; the remaining six are obtained by joining the angular points already found, as q d, e r, t i, k s, &c.

To obtain the vertical projection (No. 111) begin with the three inferior faces. The point A in the horizontal projection being the summit of the inferior solid angle, will have its vertical in a; the points b c f, when raised to the height g G, will be in b c f, or simply b f. The points b g c being in a plane perpendicular to

the vertical plane, will necessarily have the same vertical projection, b. The line a f will be the projection of the arris A f, and a b will be that of the arrises A b, A c, and of the line A g, or rather that of the triangle A b c, which is in a plane perpendicular to the vertical plane. But this triangle is only a portion of the given pentagonal face (No. 1), of which A H is the perpendicular let fall from A on the side E D. Produce a b to e, making a e equal to A H; e is the vertical projection of the arris e d. This arris is common to the inferior pentagon, and to the superior pentagon e d q p r, which is also perpendicular to the vertical plane, and, consequently, its vertical projection will be e p, equal to a e.

This projection can now be obtained by raising a vertical line through p, the summit of the superior pentagon, and from e as a centre, and with the radius A H or A H, describing an arc cutting this line in p, the point sought. But p n o belong to the base of the superior pyramid; therefore, if a perpendicular is drawn from n through y z to n, and the height p is transferred to n by drawing through p′ a line parallel to y z, n will be the projection of the points n and o. Through n draw s n a parallel to a e cutting perpendiculars drawn through s and A in the horizontal projection. Through s draw s f parallel to p e, and join a f, a p; set off on the perpendicular from r the height of s above y z at r, and draw r t parallel to y z, cutting the perpendicular from t, and joint n t. Draw perpendiculars from k and i through y z, to k and i, make k and i the same height as e, and draw k i, and join i b, i t. The vertical projection is now complete.

XXII. In a given sphere to inscribe a tetrahedron, a hexahedron or cube, an octahedron and a dodecahedron.

Let A B (Fig. 30) be the diameter of the given sphere. Divide it into three equal parts, D B being one of these parts. Draw D E perpendicular to A B, and draw the chords A E, E B. A E is the arris of the tetra-

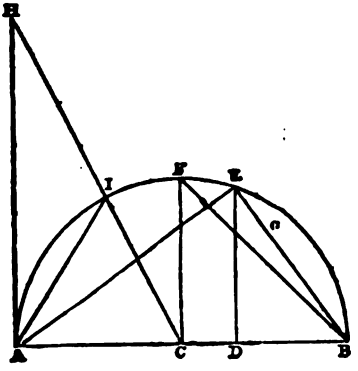


Fig. 30.

hedron, and E B the arris of the hexahedron or cube. From the centre C draw the perpendicular radius C F, and the chord F B is the arris of the octahedron. Divide B E in extreme and mean proportion in G, and B G is the arris of the dodecahedron. The arrises being known, the solids can be drawn by the help of the problems already solved. Draw the tangent A H equal to A B; join H C and A I; A I is the arris of an icosahe-

dron which can be inscribed in the sphere, an ic
hedron being a solid with twenty equal sides, all
which are equilateral triangles. See Fig. 30½.

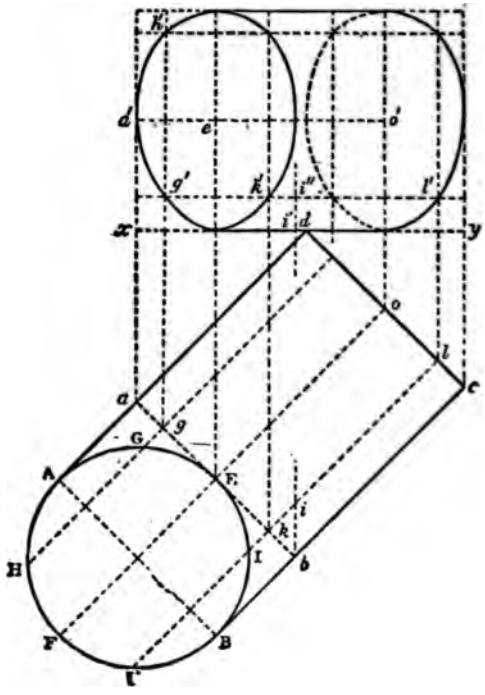


Fig. 30½.

4. THE CYLINDER, CONE, AND SPHERE.

XXIII. The horizontal projection of the cylinder, the axis of which is perpendicular to the horizontal plane, being given to find the vertical projection.

Let the circle A B C D (Fig. 31) be the base of the cylinder, and also its horizontal projection. From the points A and C raise perpendiculars to the ground-line

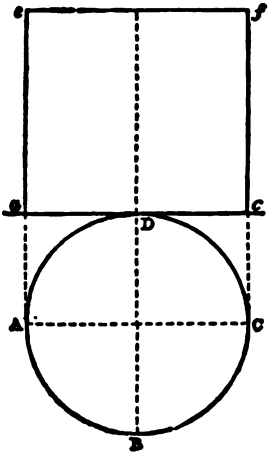


Fig. 31.

a c, and produce them to the height of the cylinder—say, for example, a e, c f. Draw e f parallel to a c, and the rectangle a e f c is the vertical projection required.

XXIV. Given the traces of an oblique plane, to determine the inclination of the plane to both the H. P. and the V. P.

Let v t and h t (Fig. 32) be the traces of the given plane. Draw the projections of a semi-cone having its axis a′ b′ in the vertical plane, the apex a′ in the given v t and its base (a semi-circle) c e d in the h p and lying tangentially to the given h t. Then the base angle (0) of the cone gives the inclination of the plane to the h p. To determine the inclination of the plane to the v. p., draw the projections of a second semi-cone, having the axis m n in the h p, and the apex m in the

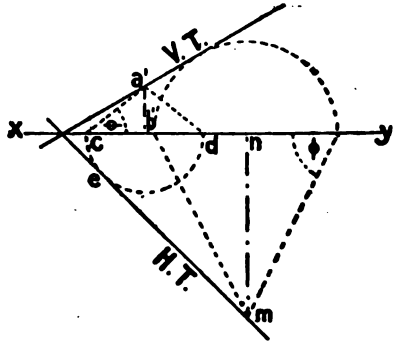


Fig. 32.

given h t, while the base is in the v p and tangential to the v t. The base angle (0) of this cone gives the inclination to the v p.

XXV. The base of a cylinder being given, and also the angles which the base makes with the planes of projection, to construct the projections of the cylinder.

Let the circle AGBH (Fig. 33) be the given base, and let each of the given angles be 45°. Draw the diameter AB, making an angle of 45° with the ground line or ver-

tical plane, and draw the line A B, making with A B the given angle; and from A as a centre, with A B and A C as radii, describe arcs cutting A B in B and C. Then draw A D, B E perpendicular to A B and equal

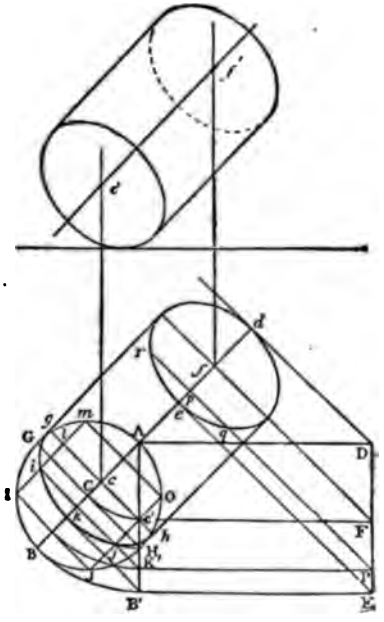


Fig. 33.

to the length of the cylinder; the rectangle A E is the vertical projection of the cylinder parallel to the vertical plane and inclined to the horizontal plane A B in an angle of 45°. Now prolong indefinitely the diameter B A, and this line will represent the projection on the horizontal plane of the line in which the generating circle moves to produce the cylinder.

If from B and C perpendiculars be let fall on A B, k will be the horizontal projection of B, A k that of the diameter A B, and c that of the centre C. Through c draw h g perpendicular to A B, and make c h, c g equal to C H, G G; and the two diameters of the ellipse, which is the projection of the base of the cylinder, will be obtained; namely, A k and h g.

In like manner, draw D F E the lines D d, F f, E e, perpendicular to the diameter A B produced, and their intersections with the diameter and the sides of the cylinder will give the means of drawing the ellipse which forms the projection of the farther end of the cylinder. The ellipses may also be found by taking any number of points in the generating circle as I J, and obtaining their projections i j. The method of doing this, and also of drawing the vertical projection e f, will be understood without further explanation.

XXVI. A point in one of the projections of a cone being given, to find it in the other projection.

Let a (Fig. 34) be the given point. This point belongs equally to the circle which is a section of the cone by a plane passing through the point parallel to the base, and to a straight line forming one of the sides of a triangle which is the section of the cone by a plane perpendicular to its base and passing through its vertex and through the given point, and of which f a g is the horizontal, and f a g the vertical projection. To find the vertical projection of a, through a draw a a perpendicular to b c, and its intersection with f g is the point required; and reciprocally, a in the

horizontal projection may be found from a in the vertical projection, in the same manner.

Otherwise, through a, in the horizontal projection, describe the circle a d c, and draw e e or c c, cutting

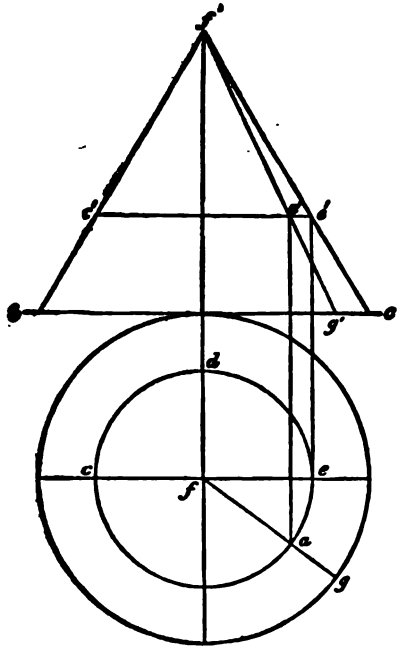


Fig. 34.

the sides of the cone in e and c; draw c e parallel to the base, and draw a a, cutting it in a, the point required.

XXVII. On a given cylinder to describe a helix.

Let a b c d, &c. (Fig. 35), be the horizontal projection of the given cylinder. Take on this curve a series of equal distances, a b, b c c d, &c., and through each

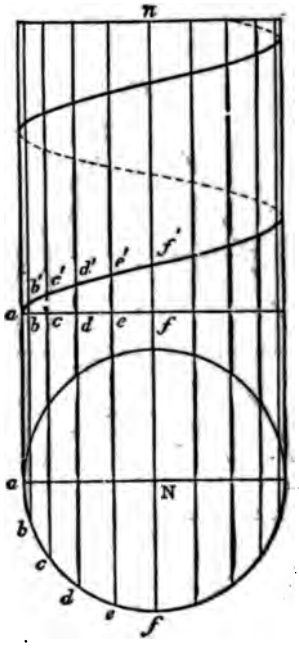


Fig. 35.

of the points a, b, c, &c. draw a vertical line, and produce it along the vertical projection of the cylinder. Then conceive a curve cutting all these verticals in the points a b c d, in such a manner that the height of the point above the ground-line may be in constant relation to the arcs a b, b c, c d; for example, that a may

be the zero of height, that bb may be 1, c c 2, d d 3, &c.; then this curve is named a helix. To construct this curve, carry on the vertical projection on each vertical line such a height as has been determined, as 1 on b, 2 on c, 3 on d; and through these points will pass the curve sought. It is easy to see that the curve

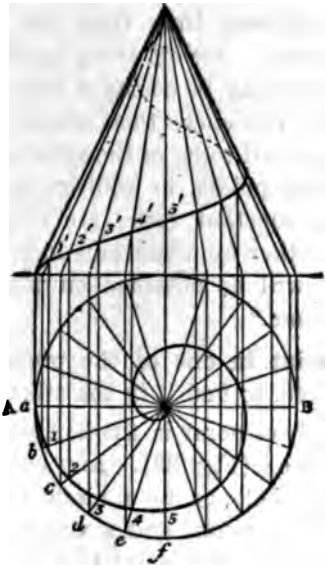


Fig. 36.

so traced is independent of the cylinder on which it has been supposed to be traced; and that if it be isolated, its horizontal projection will be a circle. The helix is named after the curve which is its horizontal projection. Thus the helix in the example is a helix with a circular base. The vertical line f n is the axis

of the helix, and the height b b, comprised between two consecutive intersections of the curve with a vertical, is the pitch of the helix.

XXVIII. On a given cone to describe a helix.

Let the projections of the given cone be as shown in Fig. 36. Divide the base of the cone in the horizontal projection into any number of equal parts, as a b, b c, c d, &c., and draw lines from the vertex to the points thus obtained. Set off along these lines a series of distances increasing in constant ratio, as 1 at b, 2 at c, 3 at d, &c. The curve then drawn through these points when supposed to be in the same plane, is called a spiral. If these points, in addition to approaching the centre in a constant ratio, are supposed also to rise above each other by a constant increase of height, a helical curve will be obtained on the vertical projection of the cone.*

XXIX. A point in one of the projections of the sphere being given, to find it in the other projection.

Let a be the given point in the horizontal projection of the sphere h b c i (Fig. 38). Any point on the surface of a sphere belongs to a circle of that sphere. Therefore, if a is a point, and a vertical plane b c is made to pass through that point to A B, the section of

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*The octahedron is formed by the union of eight equilateral triangles; or, more correctly, by the union of two pyramids with square bases, opposed base to base, and of which all the solid angles touch a sphere in which they may be inscribed.

It is essential that the diagram should be clearly *seen* as a solid, and not as a mere set of lines in one plane. Imagine K as the apex of one pyramid on the base *k* C B *i*, and A as the apex of the other pyramid on the opposite side of the same base. The octahedron is shown to be lying on its side A B C.

the sphere by this plane will be a circle, whose diameter will be b c, and the radius consequently, d b or d c; and the point a will necessarily be in the circumference of this circle. Since the centre d of this circle is situated on the horizontal axis of the sphere, and

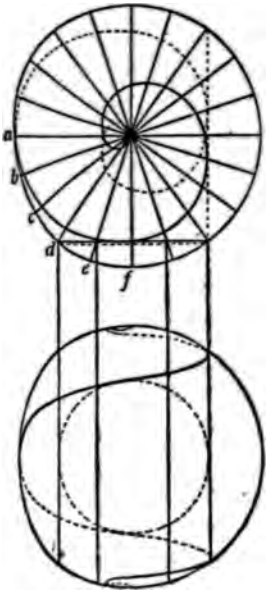

Fig. 37.

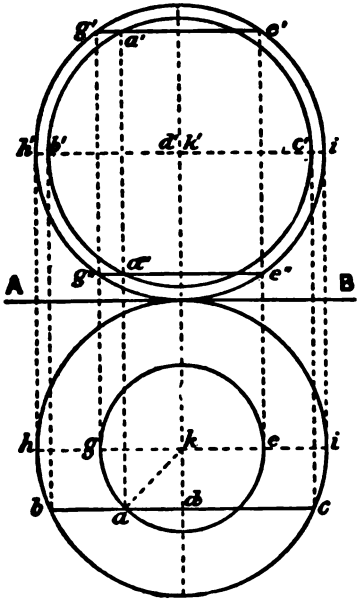

Fig. 38.

as this axis is perpendicular to the vertical plane, its vertical projection will be the point d. It is evident that the vertical projection of the given point a will be found in the circumference of the circle described from d with the radius d b or d c and at that point of it where it is intersected by the line drawn through

a, perpendicular to A B. Its vertical projection will therefore be either a or a, according as the point a is on the superior or inferior semi-surface of the sphere.

The projection of the point may also be found thus: Conceive the sphere cut by a plane parallel to the horizontal plane of projection passing through the given point a. The resulting section will be the horizontal circle described from k, with the radius k a; and the vertical projection of this section will be the straight line g e, or g e; and the intersections of these lines with the perpendicular drawn through a, will be the projection of a, as before.

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5. SECTIONS OF SOLIDS.

To draw sections of any solid requires little more than the application of the method described in the foregoing problems. Innumerable examples might be given, but a few selected ones will suffice.

XXX. The projections of a regular tetrahedron being given, to draw the section made by a plane perpendicular to the vertical plane and inclined to the horizontal plane.

Let A B C D and a b c d (Fig. 39) be the given projections, and E F G the given plane perpendicular to the vertical plane and inclined to the horizontal plane at an angle of 30°. The horizontal projection e f g of the section is easily found as shown. To find the correct section draw through e, f, and g, lines parallel to

the ground-line A C, and a c one of them as E e set off the distances E F, E G at E f and E g, and through f and g draw perpendiculars cutting the other lines in F and G'. Join E G, G F, and F E. E F G is the correct section made by the plane.

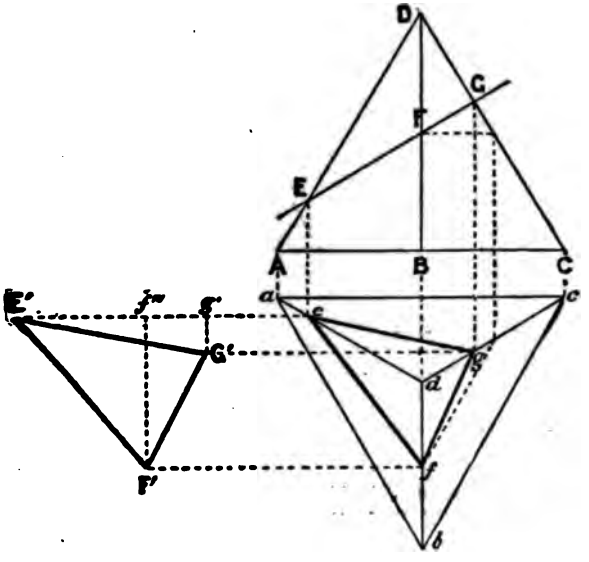


Fig. 39.

XXXI. The projections of a hexagonal pyramid being given, to draw the section made by a plane perpendicular to the vertical plane and inclined to the horizontal plane.

Let A B C D and a b c d e f g (Fig. 40) be the given projections, and H I J K the given plane. The hori-

zontal projection h i j k l m of the section is easily found as shown. Through m, l, h, j, and i draw lines parallel to the ground-line A D, and on one of them as h m, set off the distances H I, H J, H K, at h M,

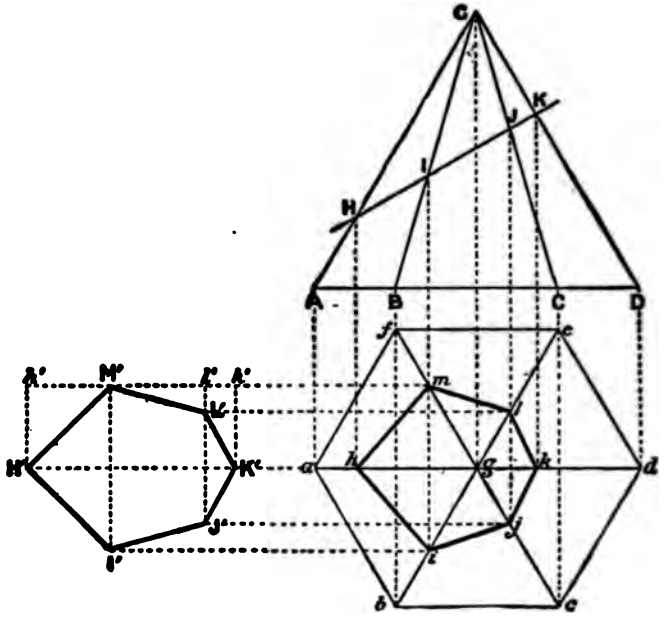


Fig. 40.

h l, h k. From h, M, l, and k draw perpendiculars meeting the other lines in H, I, L, J, and K, and join the points of intersection. H I J K L M is the true section made by the plane.

XXXII. The projections of an octagonal pyramid being given, to draw the section made by a vertical plane.

Let A B C D F and a b c d e f (Fig. 41) be the given projections, and g h i j k of the section made by the plane is easily found by drawing g g, h h, i i, &c., perpen-

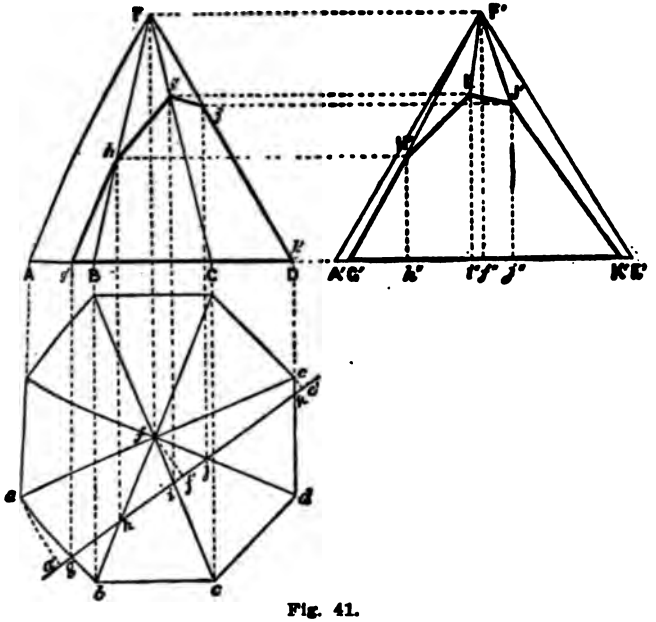


Fig. 41.

dicular to the ground-line A D. On A D produced set off the distances g h, h i, i j, and j k at G h, h i, &c., and from the points thus found draw perpendiculars to G K meeting lines drawn from h, i, and j parallel to A D, in H, I, and J. Join G H, H I, I J, and J K. G H I J K is the true section made by the plane.

A cylinder may be cut by a plane in three different ways—1st, the plane may be parallel to the axis; 2nd, it may be parallel to the base; 3rd, it may be oblique to the axis or the base.

In the first case the section is a parallelogram, whose length will be equal to the length of the cylinder, and whose width will be equal to the chord of the circle of the base in the line of section. Whence it follows, that the largest section of this kind will be that made by a plane passing through the axis; and the smallest will be when the section plane is a tangent—the section in that case will be a straight line.

When the section plane is parallel to the base, the section will be a circle equal to the base. When the section plane is oblique to the axis or the base, the section will be an ellipse.

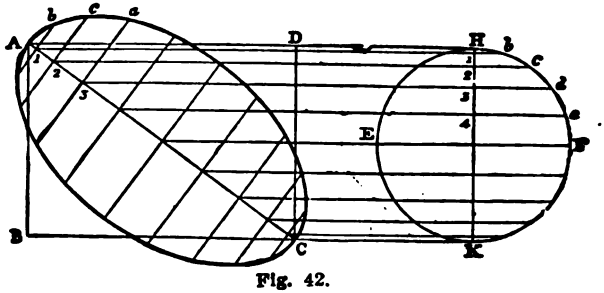


Fig. 42.

XXXIII. To draw the section of a cylinder by a plane oblique to the axis.

Let A B C D (Fig. 42) be the projection of a cylinder, of which the circle E H F K represents the base divided into twenty equal parts at b c d e, &c., and let it be required to draw the section made by the plane

A C. The circular base must be drawn in such a position that the axis of the cylinder when produced meets the centre of the circle. Through the centre of the circle draw the diameter H K perpendicular to the axis produced. Then through the divisions of the base, b c d, &c., draw lines parallel to the axis, and meeting the section plane in 1, 2, 3, &c., and through these points draw perpendiculars to A C making them equal to the corresponding perpendiculars from H K, i e, 1 b, 2 c, 3 d, &c. A curve drawn through the points thus found will be an ellipse, the true section of A B C D on the plane A C.*

The Cone. A cone may be cut by a plane in five different ways, producing what are called the conic sections: 1st. If it is cut by a plane passing through the axis, the section is a triangle, having the axis of a cone as its height, the diameter of the base for its base, and the sides for its sides. If the plane passes through the vertex, without passing through the axis, as c e (Fig. 43), the section will still be a triangle, having for its base the chord c e, for its altitude the line c e, and for its sides the sides of the cone, of which the lines c e, o e are the horizontal and the line c e the vertical projections. 2nd. If the cone is cut parallel to base, as in g h, the section will be a circle, of which g h will be the diameter. 3rd. When the section plane is oblique to the axis, and passes through the opposite sides of the cone, as m p h, the section will be an ellipse, m n h. 4th. When the plane is parallel to one of the sides of the cone, as r h, the resulting sec-

*The point is assumed to be in the inferior half of the cylinder.

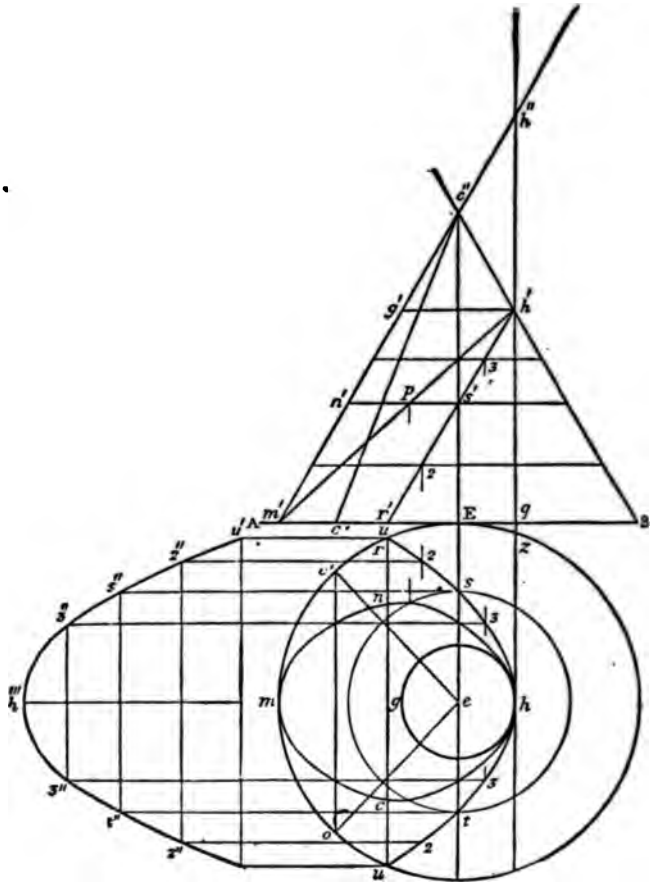


Fig. 43.

tion is a parabola r s h t u. 5th. When the section plane is such as to pass through the sides of another cone formed by producing the sides of the first be-

yond the vertex, as the plane q h, the resulting curve in each cone in a hyperbola.

Several methods of drawing the curves of the conic sections have already been given in Plane Geometry, Vol. 1. Here their projections, as resulting from the sections of the solid by planes, are to be considered. If the mode of finding the projections of a point on the surface of a given cone be understood, the projections of the curves of the conic sections will offer no difficulty. Let the problem be: First, to find the projections of the section made by the plane m h. Take at pleasure upon the plane the several points, as p, &c. Let fall from these points perpendiculars to the horizontal plane, and on these will be found the horizontal projection of the points; thus, in regard to the point p ——. Draw through p a line parallel to A B: this line will be the vertical projection of the horizontal plane cutting the cone, and its horizontal projection will be a circle, with s n for its radius. With this radius, therefore, from the centre e, describe a circle cutting, twice, the perpendicular let fall from p; the points of intersection will be two points in the horizontal projection of the circumference of the ellipse. In the same manner, any other points may be obtained in its circumference. The operation may often be abridged by taking the point p in the middle of the line m h; for then m h will be the horizontal projection of the major axis, and the two points found on the perpendicular let fall from the central point p will give the minor axis.

To obtain the projections of the parabola, more points are required, such as r, 2, s, 3, h, but the mode

of procedure is the same as for the ellipse. The vertical projection of the parabola u s h t u is shown at u s h t u.

The projections of the section plane which produces the hyperbola are in this case straight lines, q h, z h.

XXXIV. To draw the section of a cone made by a plane cutting both its sides, i. e., an ellipse.

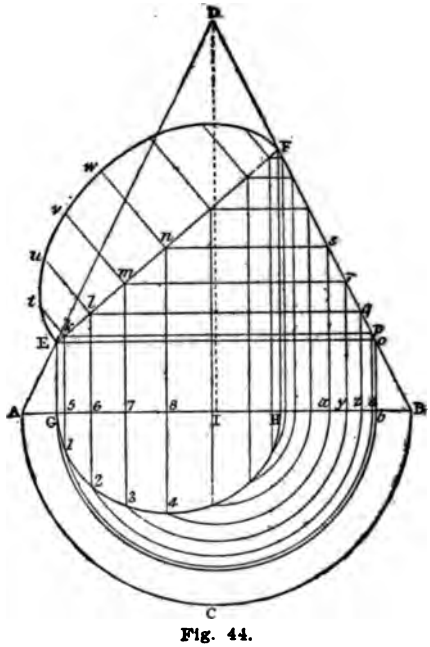


Fig. 44.

Let A D B (Fig. 44) be the vertical projection of the cone A C B the horizontal projection of half its base, and E F the line of section. From the points E and F let fall on A B the perpendiculars E G, F H.

Take any points in E F, as k, l, m, n, &c., and from them draw lines parallel to A B, as k p, l q, m r, &c., and also lines perpendicular to A B, as k l, 12 m 3, &c. Also from p, q, r, &c., let fall perpendiculars on A B, namely, p a, q z, r y, &c. From the centre of the base of the cone, l, with radius la, lz, ly, &c., describe arcs cutting the perpendiculars let fall from k, l, m, &c., in 1, 2, 3, &c. A curve traced through these points will be the horizontal projection of the section made by the plane E F. To find the true section,—Through k, l, m, &c., draw kt, lu, m v, n w, perpendicular through E F, and make them respectively equal to the corresponding ordinates, 5 1, 6 2, 7 3, &c., of the horizontal projection G 4 H, and points will be obtained through which the half E w F of the required ellipse can be traced. It is obvious that, practically it is necessary only to find the minor axis of the ellipse, the major axis E F being given.

XXXV. To draw the section of a cone made by a plane parallel to one of its sides, i. e., a parabola.

Let A D B (Fig. 45) be the vertical projection of a right cone, and A C B half the plan of its base; and let E F be the line of section. In E F take any number of points, E, a, b, c, e, F, and through them draw lines E H, a 6 1, b 7 2, &c., perpendicular to A B, and also lines parallel to A B, meeting the side of the cone in f, g, h, k, 1: from these let fall perpendiculars on A B, meeting it in m n, o, p, q. From the centre of the base l, with the radii lm, ln, lo, &c., describe arcs cutting the perpendiculars let fall from the section line in the points 1, 2, 3, 4, 5; and through the points of intersection trace the line H 12345G, which is the horizontal

projection of the section. To find the true section, from E, a, b, c, d, e, raise perpendiculars to E F, and make them respectively equal to the ordinates in the horizontal projection, as E r equal to E H, a s equal to

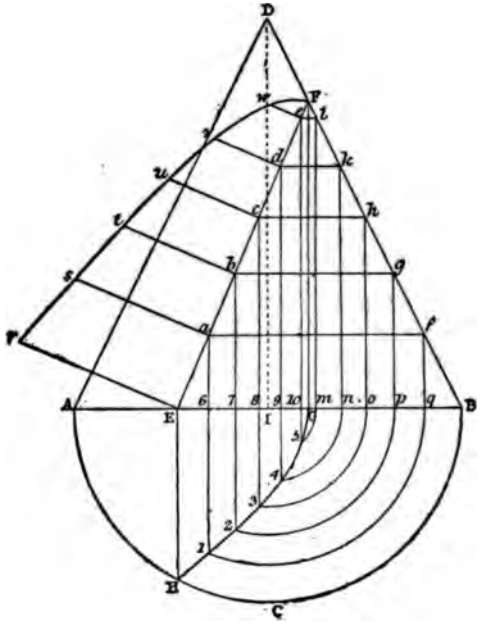


Fig. 45.

6 1, &c., and the points r s t u v w in the curve will be obtained. The other half of the parabola can be drawn by producing the ordinates w e, v d, &c., and setting the same distances to the right of E F.

XXXVI. To draw the section of a cone made by a plane parallel to the axis, i. e., an hyperbola.

Let d c d (Fig. 46) be the vertical projection of the cone, d q r d one half of the horizontal projection of the base, and q r the section plane. Divide the line r q into any number of equal parts in 1, 2, 3, h, &c., and

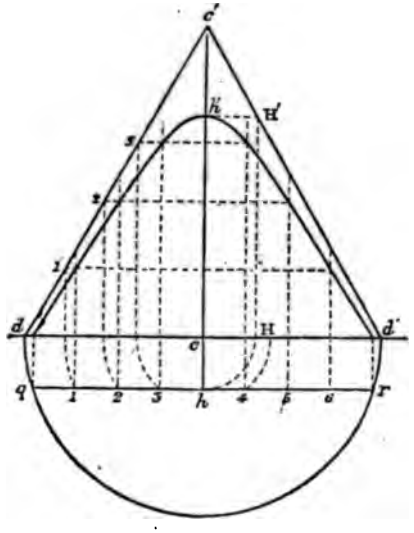


Fig. 46.

through them draw lines perpendicular to d d. From c as centre, with the radii c1, c2, &c., describe the arcs cutting d d; and from the points of intersection draw perpendiculars cutting the sides of the cone in 1, 2, 3, and these heights transferred to the corresponding perpendiculars drawn directly from the points 1, 2, 3, &c., in r q, will give points in the curve.

XXXVII. To draw the section of a cuneoid made by a plane cutting both its sides.

Let A C B (No. 1, Fig. 47) be the vertical projection of the cuneoid, and A 5 B the plan of its base, and A B (No. 4) the length of the arris at C, and let D E be the line of section. Divide the semi-circle of the base into any number of parts, 1, 2, 3, 4, 5, &c., and through them draw perpendiculars to A B, cutting it in l, m, n, o, p, &c., and join Cl, C m, Cn, &c., by lines cutting the section line in 6, 7, 8, 9 &c. From these points draw lines perpendicular to D E and make them equal to the corresponding ordinates of the semi-circle, either by transferring the lengths by the compasses, or by proceeding as shown in the figure. The curve drawn through the points thus obtained will give the required section.

The section on the line D K is shown in No. 2, in which A B equals D K; and the divisions e f g h k in D K, &c., are transferred to the corresponding points on A B; and the ordinates e l, f m, g n, &c., are made equal to the corresponding ordinates l1, m2, n3, of the semi-circle of the base. In like manner, the section of the line G H, shown in No. 3, is drawn.*

XXXVIII. To describe the section of a cylinder made by a curve cutting the cylinder.

Let A B D E (Fig. 48) be the projection of the cylinder, and C D the line of the section required. On A B

*A cuneoid is a solid ending in a straight line, in which, if any point be taken, a perpendicular from that point may be made to coincide with the surface. The base of the cuneoid may be of any form; but in architecture it is usually semi-circular or semi-elliptical, and parallel to the straight line forming the other end.

describe a semi-circle, and divide it into any number of parts. From the points of division draw ordinates 1 h, 2k, 3l, 4m, &c., and produce them to meet the line of section in o, p, q, r, s, t, u, v, w. Bend a rule or slip of paper to the line C D, and prick off on its points C,

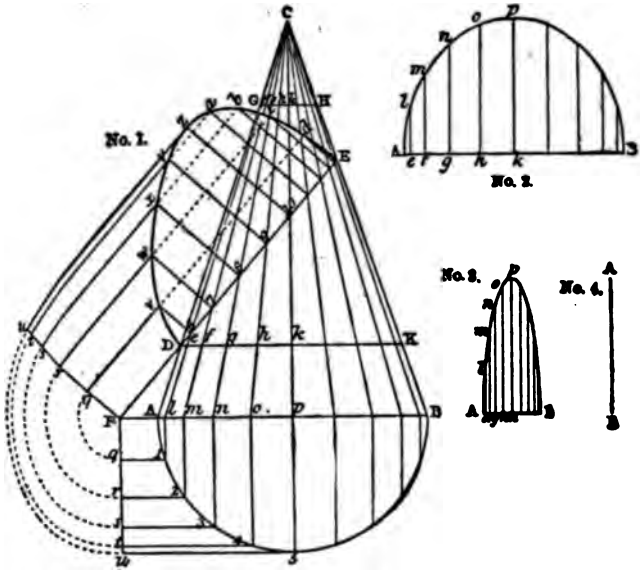


Fig. 47.

o, p, q, &c.; then draw any straight line F G, and, unbending the rule, transfer the points C, o, p, q, &c., to F, a, b, c, d, &c. Draw the ordinates a1, b 2, c 3, &c., and make them respectively equal to the ordinates h 1, k2, l 3, &c., and through the points found trace the curve.

XXXIX. To describe the section of a sphere.

Let A B D C (Fig. 49) be the great circle of a sphere, and F G the line of the section required. Then since all the sections of a globe or sphere are circles, on F G describe a semi-circle F 4G, which will be the section required.

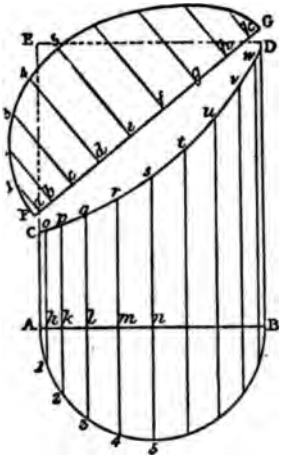


Fig. 48.

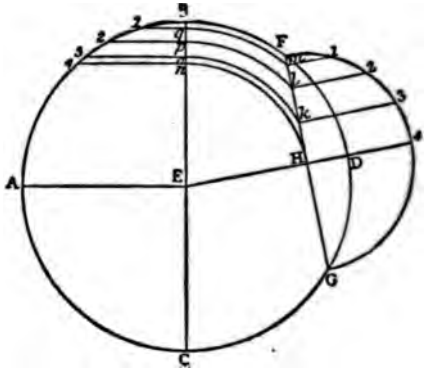


Fig. 49.

Or, in F G take any number of points, as m, l, k, H, and from the centre of the great circle E, describe the arcs H n, k o, l p, m q, and draw the ordinates H 4, k 3, l 2, ml, and n4, o3, p2, q l; then make the ordinates on F G equal to those on B C, and the points so obtained will give the section required.*

*The projections of sections of spheres are, if the section panes are oblique, either straight lines or ellipses, and are found as follows:

Let *a b* (Fig. 50) be the horizontal projection of the section plane. On the line of section take any number of points, as *a*, *c*, *b*, and through each of them draw a line perpendicular to *y x*.

XL. To describe the section of an ellipsoid when a section through the fixed axis, and the position of the line of the required section are given.

Let A B C D (Fig. 51) be the section through the fixed axis of the ellipsoid, and F G the position of the line of the required section. Through the centre of

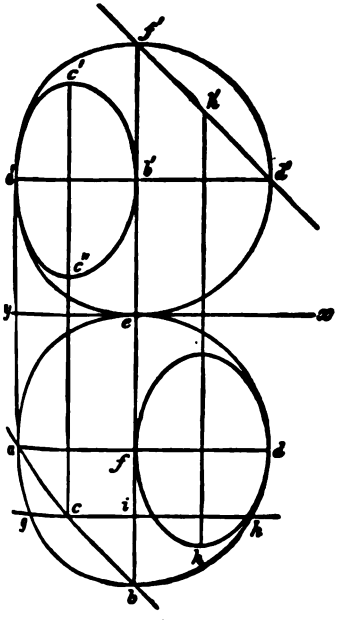


Fig. 50.

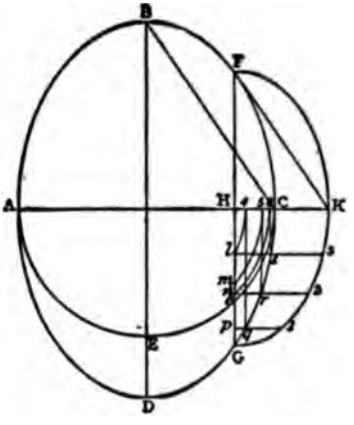


Fig. 51.

the ellipsoid draw B D parallel to F G; bisect F G in H and draw A C perpendicular to F G; join B C, and from F draw F K, parallel to B C, and cutting A C produced in K; and then will H K be the height of the semi-ellipse forming the section on F G.

Or, the section may be found by the method of ordinates, thus: As the section of the ellipsoid on the line A C is a circle, from the point of intersection of B D and A C describe a semicircle A E C. Then on H G, the line of section, take any number of points, l, m, p, and from them raise perpendiculars cutting the ellipse in q, r, s. From q, r, s draw lines perpendicular to A C, cutting it in the points 4, 5, 6; and again, from the intersection of B D and A C as centre draw the arcs 4 l, 5 m, 6n, C o, cutting H G in l, m, n, o; then H o, set off on the perpendicular from H to K, is the height of the section; and the heights H n, M m, Hl, set off on the perpendiculars from l to 3, n to 2 and p to 1, give the heights of the ordinates.

XLI. To find the section of a cylindrical ring perpendicular to the plane passing through the axis of the ring, the line of section being given.

Let A B E D (Fig. 52) be the section through the axis of the ring, A B a straight line passing through the concentric circles to the centre C, and D E be the line of section. On A B describe a semicircle; take in its circumference any points, as 1, 2, 3, 4, 5, &c., and draw the ordinates 1 f, 2 g, 3 h, 4 k, &c. Through the points f, g, h, k, l, &c., where the ordinates meet the line A B, and from the centre C, draw concentric circles, cutting the section line in m, n, o, p, q, &c. Through these points draw the lines m 1, n 2, o 3, &c., perpendicular to the section line, and transfer to them the heights of the ordinates of the semicircle f 1, g 2, &c.; then through the points 1, 2, 3, 4, &c., draw the curve D 5 E, which is the section required.

Again, let R S be the line of the required section; then from the points t, u, v, w, c, x, d, &c., where the concentric circles cut this line, draw the lines t 1, u 2, v 3, &c., perpendicular to R S, and transfer to them the corresponding ordinates of the semicircle; and through the points 1, 2, 3, 4, e, 5, f, &c., draw the curve R e f S, which is the section required.

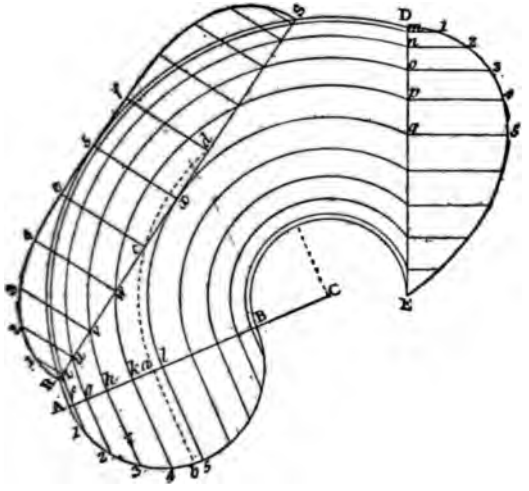


Fig. 52.

XLII. To describe the section of a solid of resolution the generating curve of which is an ogee.

Let A D B (Fig. 53) be half the plan or base of the **solid.** A a b B the vertical section through its axis, and **E F** the line of section required. From G draw C 5 **perpendicular** to E F, and bisecting it in m. In E m

take any number of points, g h k, &c., and through them draw the lines g 1, h 2, k 3, &c., perpendicular to E F. Then from C as a centre, through the points g, h, k, &c., draw concentric arcs cutting A B in r, s, t, u, v, and through these points draw the ordinates r 5, s 4, t 3, &c., perpendicular to A B. Transfer the heights of the ordinates on A B to the corresponding ordinates on each side of the centre of E F; and through the points 1, 2, 3, 4, 5, &c., draw the curve E 5 F, which is the section required.

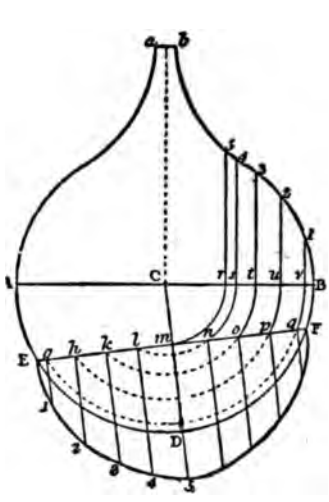


Fig. 53.

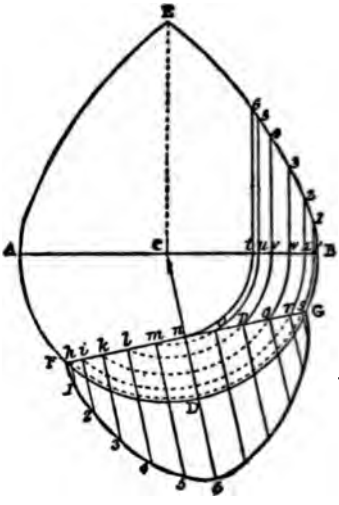


Fig. 54.

XLIII. To find the section of a solid of resolution, the generating curve of which is of a lancet form.

Let A D B (Fig. 54) be the plan of half the base, A E B the vertical section, and F G the line of the required section. The manner of finding the ordinates

and transferring the heights is precisely the same as in the last problem.

XLIV. To find the section of an ogee pyramid with a hexagonal base.

Let A D E F B (Fig. 55) be the plan of the base of the pyramid, A a b B a vertical section through its axis, and G H the line of the required section. Draw the arrises C D, C E, C F. On the line of section G H, at the points of intersection of the arrises with it, and

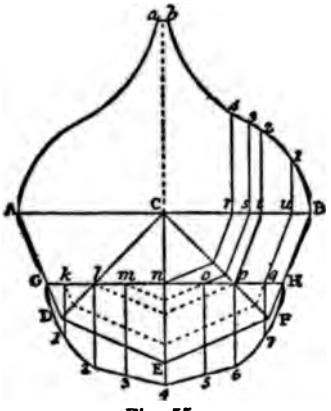


Fig. 55.

at some intermediate points k, m, o, q (the corresponding points k and q, and m and o, being equidistant from n), raise indefinite perpendiculars. Through these points k, l, m, n, o, p, q, draw lines parallel to the sides of the base, as shown by dotted lines; and from the points where these parallels meet the line A B, draw r 4, s 3, t 2, u 1, perpendicular to A B. These perpendiculars transferred to the ordinates n 4, m 3, o 5, l 2, p 6, k 1, q 7, will give the points 1, 2, 3, 4, 5, 6, 7, through which the section can be drawn.

6. INTERSECTIONS OF CURVED SURFACES.

When two solids having curved surfaces penetrate or intersect each other, the intersections of their surfaces form curved lines of various kinds. Some of these, as the circle, the ellipse, &c., can be obtained in the plane; but the others cannot, and are named curves of double curvature. The solution of the following problems depends chiefly on the knowledge of how to obtain, in the most advantageous manner, the projections of a point on a curved surface; and is in fact the application of the principles elucidated in the several previous problems. The manner of constructing the intersections of these curved surfaces which is the simplest and most general in its application, consists in conceiving the solids to which they belong as cut by planes according to certain conditions, more or less dependent on the nature of the surfaces. These section planes may be drawn parallel to one of the planes of the projection; and as all the points of intersection of the surfaces are found in the section planes, or on one of their projections, it is always easy to construct the curves by transferring these points to the other projection of the planes.

XLV. The projection of two equal cylinders which intersect at right angles being given, to find the projections of their intersections.

Conceive, in the horizontal projection (Fig. 56), a series of vertical planes cutting the cylinders parallel to their axis. The vertical projections of all the sections will be so many right-angled parallelograms, sim-

ilar to e f e f, which is the result of the section of the cylinder from surface to surface. The circumference of the second cylinder, whose axis is vertical, is cut by the same plane, which meets its upper surface at the two points g, h, and its under surface at two corresponding points. The vertical projections of these points are on the lines perpendicular to a b, raised on

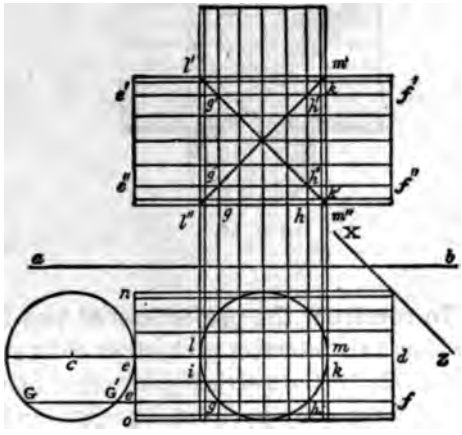


Fig. 56.

each of them, so that upon the lines e f, e f, will be situated the intersections of these lines at the points g, h, and g, h and the same with other points i, k, l, m. It is not necessary to draw a plan to find these projections. All that is actually required is to draw the circle representing one of the bases (as n o) of the cylinder laid flat on the horizontal plane. Then to produce g h till it cuts the circle at the superior and

inferior points G, G, and to take the heights e G, e G, and carry them, upon a b, from g to g g and from h to h, h.

Fig. 57 is the vertical projection made on the line x z.

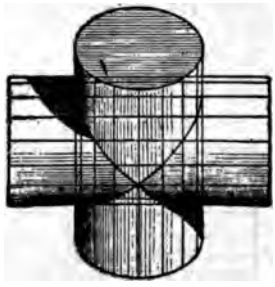


Fig. 57.

XLVI. To construct the projections of two unequal cylinders whose axis intersect each other obliquely.

Let A (Fig. 58) be the vertical projection of the two cylinders, and h S d e the horizontal projection of their axis. Conceive in the vertical projection, the cylinders cut by any number of horizontal planes; the horizontal projections of these planes will be rectangles, as in the previous example, and their sides will be parallel to the axis of the cylinders.

The points of intersection of these lines will be the points sought. Without any previous operation, six of those points of intersection can be obtained. For example the point c is situated on d e, the highest point of the smaller cylinder; consequently, the horizontal projection of c is on d e, the horizontal projection of

d e, and it is also on the perpendicular let fall from c, that is to say, on the line c f parallel to the axis of the cylinder S h. The point sought will, therefore, be the intersection of those lines at c. In the same way i is

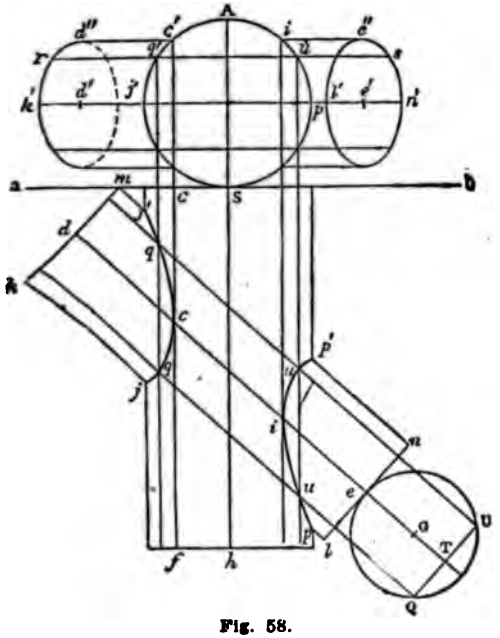


Fig. 58.

obtained. The point j is on the line k l, which is in the horizontal plane passing through the axis d e, the horizontal projections of k l are k l, and its opposite m n; therefore in letting fall perpendiculars from j p, the intersections of these with k l, m n, give the points j j,

p p. Thus six points are obtained. Take at pleasure an intermediate point q; through this point draw a line r s parallel to a b, which will be the vertical projection of a horizontal plane cutting the cylinder in q. The horizontal projection of this section will be, as in the preceding examples, a rectangle which is obtained by taking, in the vertical projection, the height of the section plane above the axis d e, and carrying it on the base in the horizontal projection from G to T. Through T is then to be drawn the line Q U perpendicular to G T; and through Q and U the lines parallel to the axis; and the points in which these lines are intersected by the perpendiculars let fall from q u are the intermediate points required. Any number of intermediate points can thus be obtained; and the curve being drawn through them, the operation is completed.

XLVII. To find the intersections of a sphere and a cylinder.

Let e f c d and i k g h (Fig. 59) be the horizontal projections of the sphere and cylinder respectively. Draw parallel to A B, as many vertical section planes are considered necessary, as e f, c d. These planes cut at the same time both the sphere and the cylinder, and the result of each section will be a circle in the case of the sphere, and a rectangle in the case of the cylinder. Through each of the points of intersection g, h, i, k, and from the centre l, draw indefinite lines perpendicular to A B. Take the radius of the circles of the sphere proper to each of these sections and with them, from the centre l, cut the correspondent perpendiculars in g g, h h, i i, &c., and draw through these points the curves of intersection.

XLVIII. To construct the intersection of two right cones with circular bases.

The solution of this problem is founded on the knowledge of the means of obtaining on one of the projections of a cone a point given on the other.

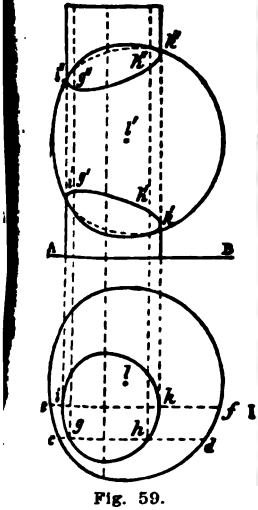


Fig. 59.

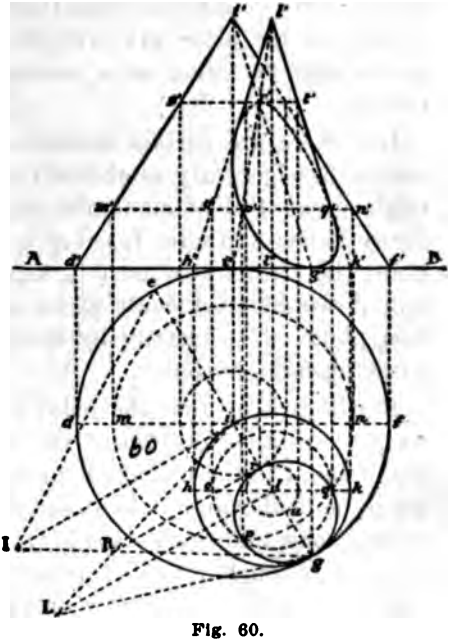


Fig. 60.

No. 1. Let A B (Fig. 60) be the common section of the two planes of projection, the circles g d e f and g h i k the horizontal projections of the given cones, and the triangles d i f and h l k their vertical projections. Suppose these cones cut by a series of horizontal planes: each section will consist of two circles, the

intersections of which will be points of intersection of the conical surfaces. For example, the section made by a plane m n will have for its horizontal projections two circles of different diameters, the radius of the one being i m, and of the other l o. The intersecting points of these are p and q, and these points are common to the two circumferences; and their vertical projection on the plane m n will be p q. Thus, as many points may be found as is necessary to complete the curve.

But there are certain points of intersection which cannot be rigorously established by this method without a great deal of manipulation. The point r in the figure is one of those; for it will be seen that at that point the two circles must be tangents to each other, and it would be difficult to fix the place of the section plane s t so exactly by trial, that it would just pass through the point.

It will be seen that the point r must be situated in the horizontal projection of the line g i a perpendicular i l equal to the height of the cone. From one raise a perpendicular and make it equal to the height of the second cone, and draw its side L i; and from the point of intersection R let fall a perpendicular on g i meeting it in r; through r draw an indefinite line perpendicular to A B, and set up on it from A B to r the height r R. The point r can also be obtained directly in the vertical projection by joining i g and l i as shown.

Bisect r g in u, and from u as a centre, with the radius u r, describe a circle, the circumference of which will be the horizontal projection of the intersec-

tion of the two cones. The vertical projection of this circle will be g p r q, and can be found by the method indicated above.

No. 2. Conceive the horizontal projection (Fig. 61, No. 1) a vertical plane C D cutting both cones through their axis: the sections will be two triangles, having

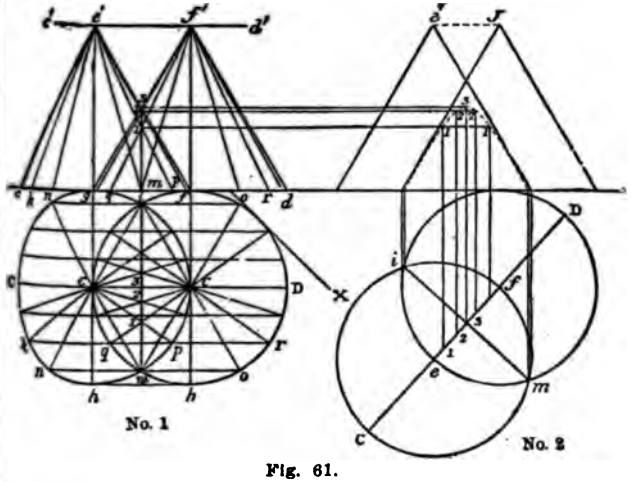


Fig. 61.

the diameters of the bases of the cones as their bases, and the height of the cones as their height. And as in the example the cones are equal, the triangles will also be equal, as the triangles c e f, g f d, in the vertical projection. Conceive now a number of inclined planes, as c n m, c k p, &c., passing through the different points of the base, but still passing through the summits of the cones; the sections which result will still be triangles (as has already been demonstrated), whose bases diminish in proportion as the planes re-

cede from the centres of the bases of the cones, until at length the plane becomes a tangent to both cones and the result is a tangent line whose projections are h c, h c, g e, f f. It will be observed that the circumferences of the bases cut each other at m and i, which are the first points of their intersections, whose vertical projections are the point m merely. If the projections of the other points of intersection on the lines of the section planes are found (an operation presenting no difficulty, and easily understood by the inspection of the figure), it will be seen that the triangles n c m, m c o, k e p, q e r, &c., in the horizontal projection, have for their vertical projections the triangles n e m, m o, k e p, &c., and that the intersections of the cones are in a plane perpendicular to both planes of projection, and the projections of the intersections are the right lines i m, m 3. From the known properties of the conic sections, the curve produced by this plane will be a hyperbola. Fig. 61, No. 2, gives the projections of the cones on the line o x.

No. 3. The next example (Fig. 62) differs from the last in the inequality of the size of the cones. Suppose an indefinite line C D to be the horizontal projection of the vertical section plane, cutting the two cones through their axis e f. Conceive in this plane an indefinite line e f D, passing through the summits of the cones, the vertical projection of this line will be e f d: from d let fall on C D a perpendicular meeting it in D; this will be the point in which the line passing through the summits of the cones will meet the horizontal plane; and it is through this point, and through the summits e and f, that the inclined section planes should

be made to pass. The horizontal traces of these planes are O D, G D, &c.: O D is then the trace of a tangent plane to the two conical surfaces O e, P f; and the plane e G D cuts the greater cone, and forms by the section the triangles G e H in the horizontal, and g e h in the vertical projection; and it cuts the lesser cone, and forms the triangles l f J, i f j. In the horizontal

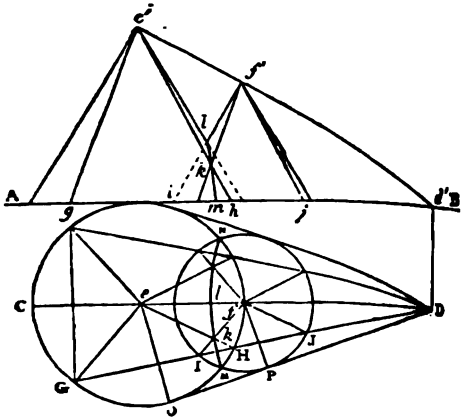


Fig. 62.

projection it is seen that the sides H e, l f of the triangles intersect in k, which is therefore the horizontal projection of one of the points of intersection; and its vertical projection is k. In the same manner, other points can be found. It is seen at once that M, N, l, are also points in the intersection. The curves traced through the points M k l N in the horizontal, and m k l in the vertical projection, are the projections of the intersection of the two cones.

7. COVERINGS OF SOLIDS.

1. Regular Polyhedrons. A solid angle cannot be formed with fewer than three plane angles. The simplest solid is, therefore, the tetrahedron or pyramid having an equilateral triangle for its base, and its other three sides formed of similar triangles.

The development of this figure (Fig. 63) is made by drawing the triangular base A B C, and then drawing around it the triangles forming the inclined sides. If the diagram is on flexible material, such as paper, then cut out, and the triangles folded on the lines A B, B C, C A, the solid figure will be constructed.

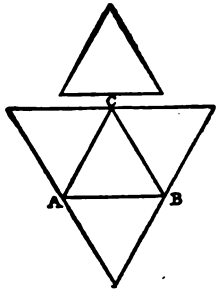


Fig. 63.

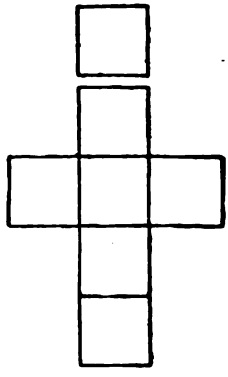


Fig. 64.

The **hexahedron**, or cube, is composed of six equal squares (Fig. 64); the **octahedron** (Fig. 65) of eight equilateral triangles; the **dodecahedron** (Fig. 66) of twelve pentagons; the **icosahedron** (Fig. 67) of twenty

equilateral triangles. In these figures, A is the elevation and B the development.

The elements of these solids are the equilateral triangle, the square, and the pentagon. The irregular polyhedrons may be formed from those named, by cutting off the solid angles. Thus, in cutting off the

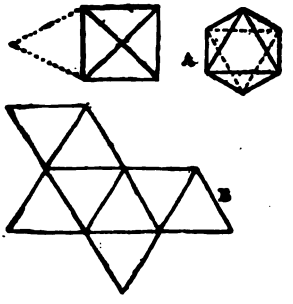


Fig. 65.

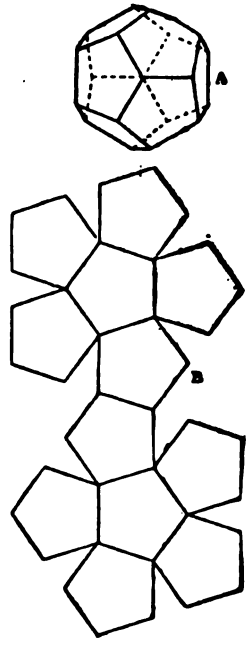


Fig. 66.

angles of the tetrahedron, there results a polyhedron of eight faces, composed of four hexagons and four equilateral triangles. The cutting off the angles of the cube, in the same manner gives polyhedron of four-

teen faces, composed of six octagons, united by eight equilateral triangles.

The same operation performed on the octahedron produces fourteen faces, of which eight are hexagonal and six square; on the dodecahedron it gives thirty-two sides, namely, twelve decagons, and twenty triangles; on the icosahedron it gives thirty-two sides—twelve tentagons and twenty hexagons. This last approaches almost to the globular form and can be rolled like a ball.

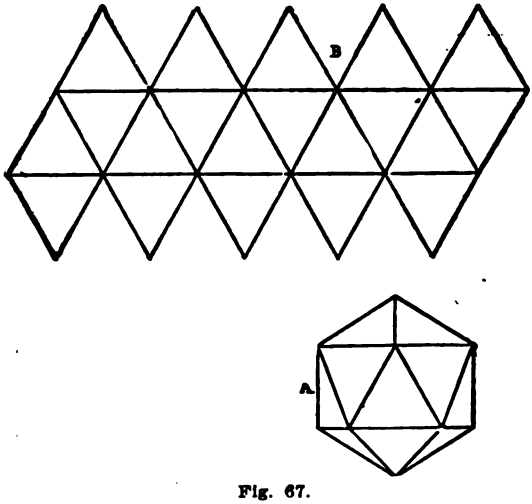


Fig. 67.

The other solids which have plane surfaces are the pyramids and prisms. These may be regular and irregular: they may have their axis perpendicular or inclined; they may be truncated or cut with a section, parallel or oblique, to their base.

II. Pyramids. The development of a right pyramid, of which the base and the height are given, offers no difficulty. The operation consists (Fig. 68) in elevating on each side of the base, a triangle having its height equal to the inclined height of each side, or, otherwise, connecting the sides, together as shown by the dotted lines.

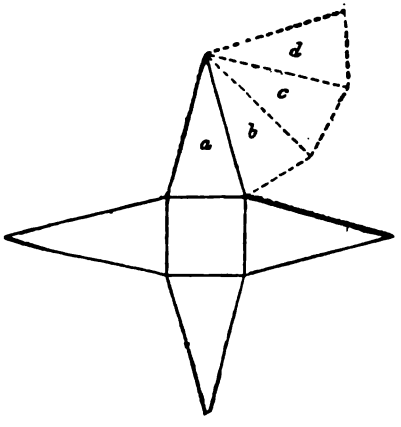


Fig. 68.

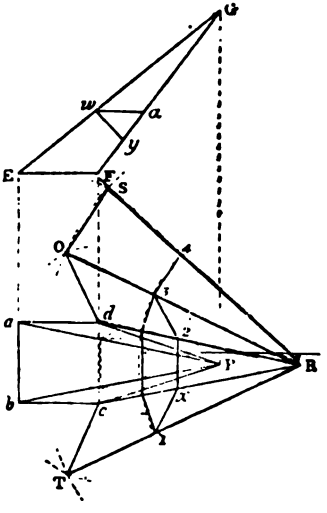


Fig. 69.

In an oblique pyramid the development is found as follows: Let a b c d (Fig. 69) be the plan of the base of the pyramid, a b c d its horizontal projection, and E F G its vertical projection. Then on the side d c construct the triangle c R d, making its height equal to the sloping side of the pyramid F G. This triangle is the development of the side d P c of the pyramid.

Then from d, with the radius E F, describe an arc O; and from R, with the radius equal to the true length. e G of the arris E G, describe another arc intersecting the last at O. Join R O, d O; the triangle d R O will be the development of the side a P d. In the same way, describe the triangle c R T, for the development of the side b P c. From R, again, with the same radius R O, describe an arc S, which intersect by an arc described from O with the radius a b; and the triangle O R S will be the development of the side a P b.

If the pyramid is truncated by a plane w a parallel to the base, the development of that line is obtained by setting off from R on R c, and R d, the true length of the arris G a in x and 2, and on R S, R O, and R T, the true length of the arris G w in 4, 3, 1; and drawing the lines 1 x, x2, 2 3, 3 4, parallel to the base of the respective triangles T R c, c R d, d R O, O R S. If it is truncated by a plane w y, perpendicular to the axis, then from the point R, with the radius equal to the true length of the arris G w, or G y, describe an arc 1 4, and inscribe in it the sides of the polygon forming the pyramid.

III. **Prisms.** In a right prism, the faces being all perpendicular to the bases which truncate the solid, it results that their development is a rectangle composed of all the faces joined together, and bounded by two parallel lines equal in length to the contour of the bases. Thus, in Fig. 70, a b c d is the base, and b e the height of the prism; the four sides will form the rectangle b e f g, and e h i k will be the top of the prism. The full lines show another method of development.

When a prism is inclined, the faces form different

angles with the lines of the contours of the bases; whence there results a development, the extremities of which are bounded by lines forming parts of polygons.

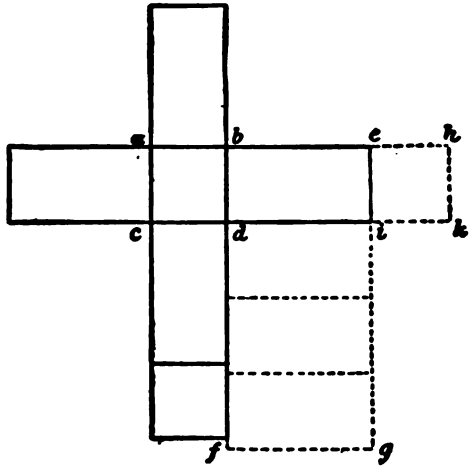


Fig. 70.

After having drawn the line C C (Fig. 71), which indicates the axis of the prism and the lines A B, D E, the surfaces which terminate it, describe on the middle of the axis the polygon forming the plan of the prism, taken perpendicularly to the axis, and indicated by the figures 1 and 8. Produce the sides 1 2, 6 5, parallel to the axis, until they meet the lines A B, D E. These lines then indicate the four arrises of the prism, corresponding to the angles 1 2 5 6. Through the points

8 3 7 4 draw lines parallel to the axis meeting A B, D E in F H, G L. These lines represent the four arrises 8 3 7 4.*

In this profile the sides of the plan of the polygon 1 2 3 4 5 6 7 8 give the width of the faces of the prism,

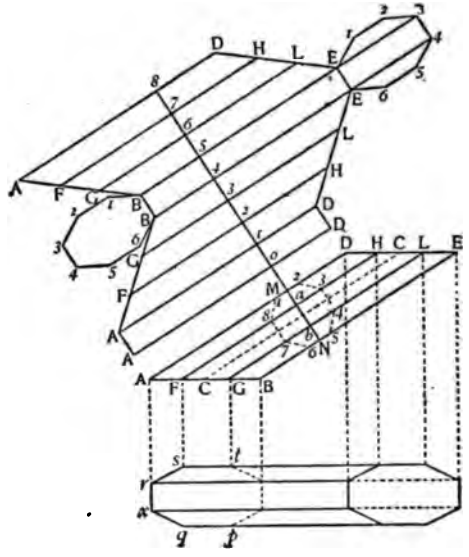


Fig. 71.

and the lines A D, F H, G L, B E their length. From this profile can be drawn the horizontal projection, in the manner shown below. To trace the development of this prism on a sheet of paper, so that it can be folded

*In Fig. 75 another example is given, but as the method of procedure is the same as in Fig. 71, detailed description is unnecessary.

together to form the solid, proceed thus: On the middle of C C raise an indefinite perpendicular M N. On that line set off the width of the faces of the prism, indicated by the polygon, in the points 0 1 2 3 4 5 6 7 8. Through these points draw lines parallel to the axis, and upon them set off the lengths of the lines in profile, thus: From the points O, 1, and 8, set off the length M D in the points D D D; from 2 and 7, set off a H in H; from 3 and 6, set off b L in L and L; and so on. Draw the lines DD, D H L E, EE, E L H D, for the contour of the upper part of the prism. To obtain the contour of the lower portion, set off the length M A from O, 1, and 8 to A A A, the length a F from 2 and 7 to F and F, the length b G from 3 and 6 to G and G, and so on; and draw A A, A F G B, B B, B G F A, to complete the contour. The development is completed by making on B B and E E the polygons 1 2 3 4 5 6 BB, 1 2 3 4 5 6 EE, similar to the polygons of the horizontal projection.

IV. Cylinders. Cylinders may be considered as prisms, of which the base is composed of an infinite number of sides. Thus we shall obtain graphically the development of a right cylinder by a rectangle of the same height, and of a length equal to the circumference of the circle, which serves as its base.

To find the covering of a right cylinder.

Let A B C D (Fig. 72) be the seat or generating section. On A D describe the semicircle A 5 D, representing the vertical section of half the cylinder, and divide its circumference into any number of parts, 1, 2, 3, 4,

5, &c., and transfer those divisions to the lines A D and B C produced; then the parallelogram D C G F will be the covering of one half the cylinder.

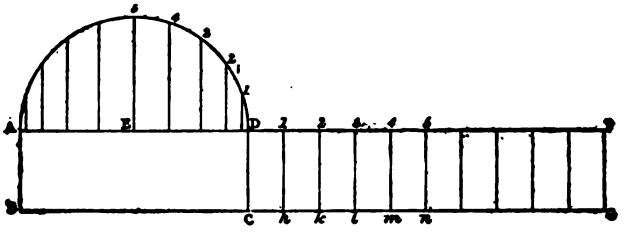


Fig. 72.

To find the edge of the covering when it is oblique in regard to the sides of the cylinder.

Let A B C D (Fig. 73) be the seat of the generating section, the edge B C being oblique to the sides A B, D C. Draw the semicircle A 5 D, and divide it into any

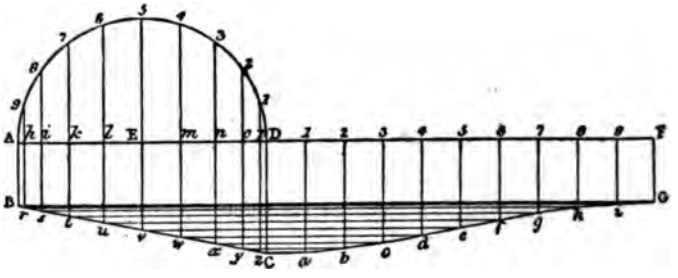


Fig. 73.

number of parts as before; and through the divisions draw lines at right angles to A D, producing them to meet B C in r s, t, u, v, &c. produce A D, and the lines 1 a, 2 b, 3 c, &c., perpendicular to D F. To these lines

transfer the length of the corresponding lines intercepted between A D and B C, that is, to la transfer the length p z, to 2 b transfer o y, and so on, by drawing the lines z a, y b, x c, &c., parallel to A F. Through the points thus obtained, draw the curved line C a b c, &c., to G; then shall D F C G be the development of the covering of the semi-cylinder A B C D.

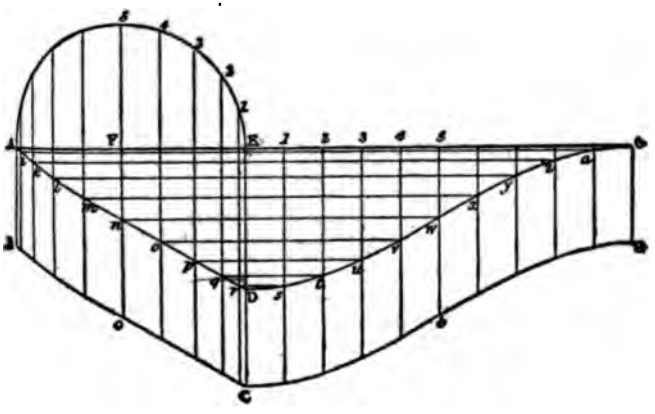


Fig. 74.

To find the covering of a cylinder contained between two oblique parallel planes.

Let A B C D (Fig. 74) be the seat of the generating section. From A draw A G perpendicular to A B, and produce C D to meet it in E. On A E describe the semicircle, and transfer its perimeter to E G, by dividing it into equal parts, and setting off corresponding divisions on E G. Through the divisions of the semicircle draw lines at right angles to A E, producing them to

meet the lines A D and B C, in i, k, l, m, &c. Through the divisions on E G draw lines perpendicular to it then through the intersections of the ordinates of the semicircle, with the line A D, draw the lines i a, k z, l y,

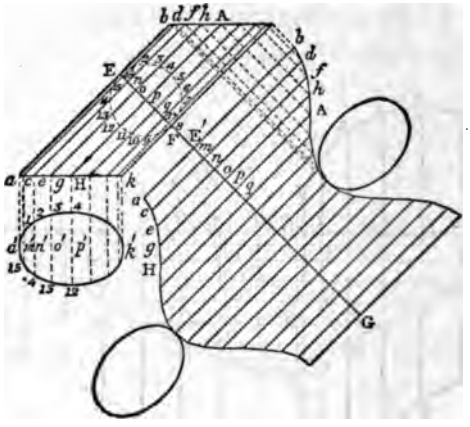


Fig. 75.

&c., parallel to A G and where these intersect the perpendiculars from E G, in the points a, z, y, x, w, u, &c., trace a curved line G D, and draw parallel to it the curved line H C; then will D C H G be the development of the covering of the semi-cylinder A B C D.

To find the covering of a semi-cylindric surface bounded by two curved lines.

The construction to obtain the developments of these coverings (Figs. 76 and 77) is precisely similar to that described in Fig. 74.

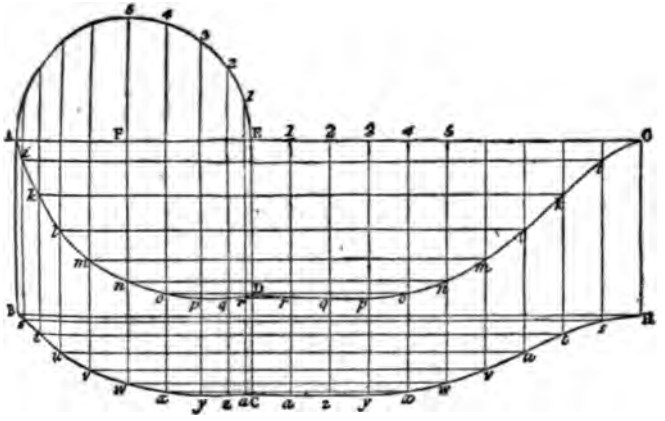


Fig. 76.

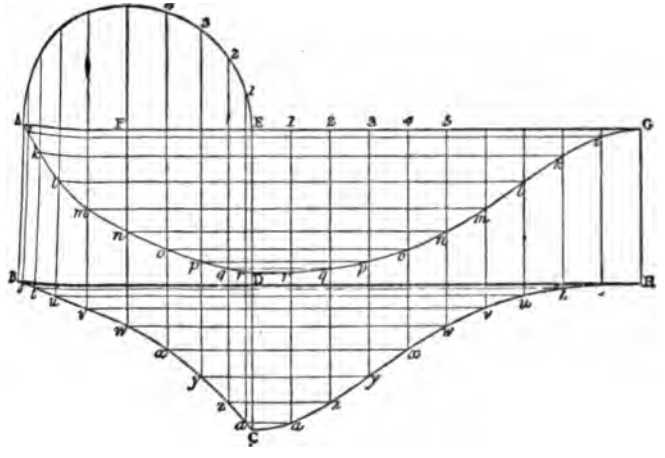


Fig. 77.

V. Cones. We have considered cylinders as prisms with polygonal bases. In a similar manner we may regard cones as pyramids.

In right pyramids, with regular symmetrical bases,

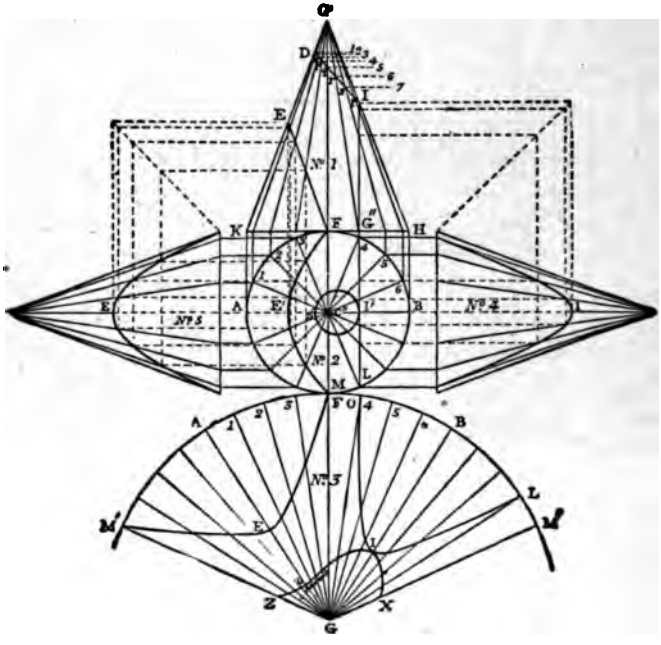


Fig. 78.

as the lines of the arrises extending from the summit to the base are equal, and as the sides of the polygons forming the base are also equal, their developed surfaces will be composed of similar and equal isosceles triangles, which, as we have seen (Fig. 78, a, b, c, d), will, when united, form a part of a regular polygon

inscribed in a circle, of which the inclined sides of the polygon form the radii. Thus in considering the base of the cone K H (Fig. 78) as a regular polygon of an infinite number of sides, its development will be found in the sector of a circle, M A F B M (No. 3), of which the radius equals the side of the cone K G (No. 1), and the arc equals the circumference of the circle forming its base (No. 2).

To trace on the development of the covering, the curves of the ellipse, parabola, and hyperbola, which are the result of the sections of the cone by the lines D I, E F, I G, it is necessary to divide the circumference of the base A F B M (No. 2) into equal parts, as 1, 2, 3, &c., and from these to draw radii to the centre C, which is the horizontal projection of the vertex of the cone; then to carry these divisions to the common intersection line K H, and from their terminations there to draw lines to the vertex G, in the vertical projection No. 1. These lines cut the intersecting planes, forming the ellipse, parabola, and hyperbola, and by the aid of the intersections we obtain the horizontal projection of these figures in No. 2—the parabola passing through M E F, the hyperbola through G I L, and the ellipse through D I.

To obtain points in the circumference of the ellipse upon the development, through the points of intersection o, p, q, r, &c., draw lines parallel to K H, carrying the heights to the side of the cone G H, in the points 1, 2, 3, 4, 5, 6, 7, and transfer the lengths G 1, G 2, G 3, &c. to G 1, G 2, G 3, G 4, &c., on the radii of the development in No. 3; and through the points thus obtained draw the curve z D l X.

To obtain the parabola and hyperbola, proceed in the same manner, by drawing parallels to the base K H, through the points of intersection; and transferring the lengths thus obtained on the sides of the cone G K, G H, to the radii in the development.

Nos. 4, and 5 give the vertical projections of the hyperbola and parabola respectively.

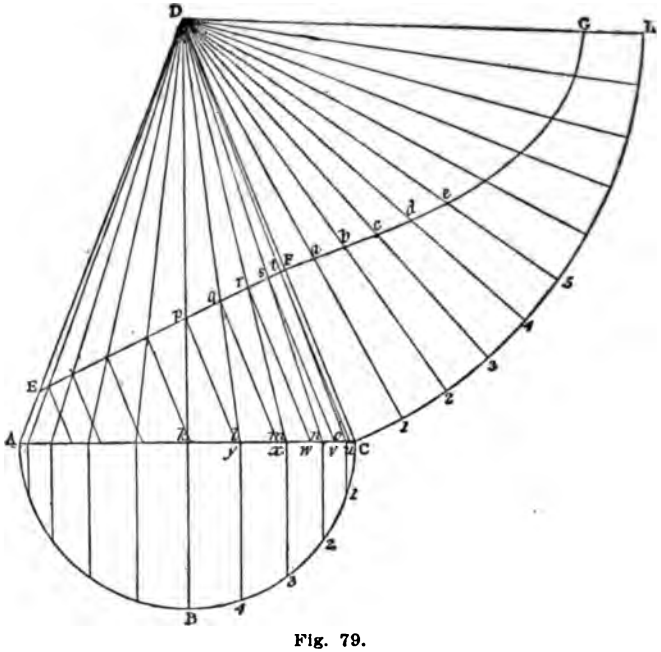


Fig. 79.

To find the covering of the frustum of a cone, the section being made by a plane perpendicular to the axis.

Let A C E F (Fig. 79) be the generating section of

the frustum. On A C describe the semicircle A B C, and produce the sides A E and C F to D. From the centre D, with the radius D C, describe the arc C H; and from the same centre with the radius D F, describe

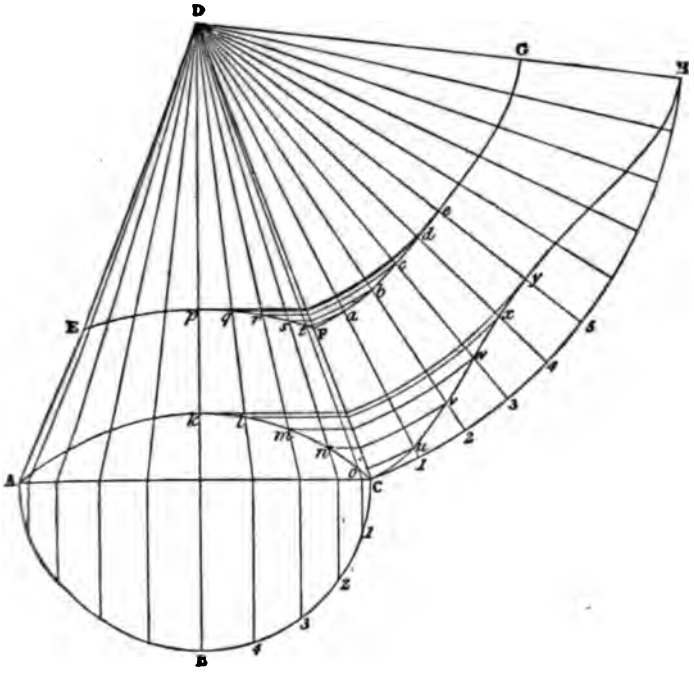


Fig. 80.

the arc F G. Divide the semicircle A B C into any number of equal parts, and run the same divisions along the arc C H; draw the line H D, cutting E G in G; then shall C H G F be half the development of the covering of the frustum A C F E.

To find the covering of the frustum of a cone, the section being made by a plane not perpendicular to the axis.

Let A C F E (Fig. 80) be the frustum. Proceed as in the last problem to find the development of the covering of the semi-cone. Then—to determine the edge of the covering of the line E F—from the points P, q, r, s, t, &c., draw lines perpendicular to E F, cutting A C in y, x, w, v, u; and the length u t transferred from 1 to a, v s, transferred from 2 to b, and so on, will give a, b, c, d, e, &c., points on the edge of the covering.

To find the covering of the frustum of a cone, when cut by two cylindrical surfaces perpendicular to the generating section.

Let A E F C (Fig. 81) be the given frustum, and A k C, E p F, the given cylindrical surfaces. Produce A E, C F, till they meet in the point D. Describe the semicircle A B C, and divide it into any number of equal parts, and transfer the divisions to the arc C H, described from D, with the radius D C. Through the divisions in the semicircle 1, 2, 3, 4, &c., draw lines perpendicular to A C, and through the points where they intersect A C draw lines to the summit D. Draw lines also through the points 1, 2, 3, 4, 5, &c., of the arc C H, to the summit D; then through the intersections of the lines from A C to D, with the seats of the cylindrical surfaces k, l, m, n, o, and p, q,r, s, t, draw lines parallel to A C, cutting C D; and from the points of intersection in C D and from the centre D, describe arcs cutting the radial lines in the sector D C H in u, v, w, x, y,

&c., and a, b, c, d, e, &c., and curves traced through the intersections will give the form of the covering.

VI. Spheres, Ellipsoids, &c. The development of the sphere, and of other surfaces of double curvature,

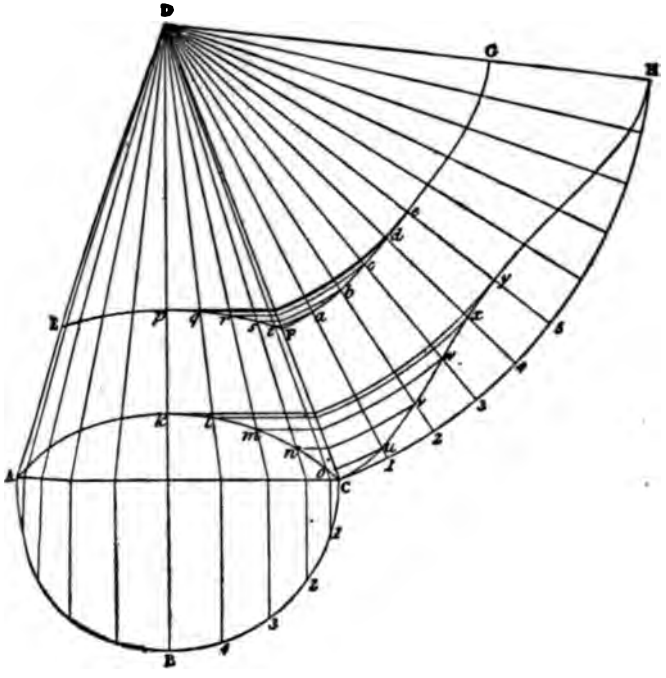


Fig. 81.

is impossible, except on the supposition of their being composed of a great number of small faces, either plane, or of a simple curvature, as the cylinder and the

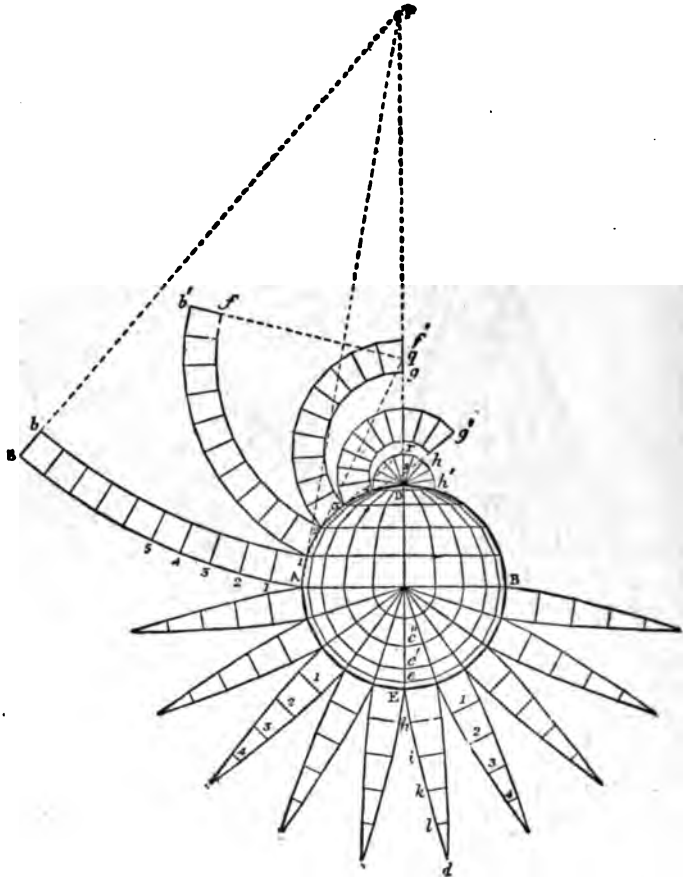


Fig. 82.

cone. Thus, the sphere or spheroid may be considered as a polyhedron, terminated, 1st, by a great number of plane faces, formed by truncated pyramids, of which the base is a polygon, as in Fig. 82; 2nd, by parts of

truncated cones forming zones, as in Fig. 83, the part above A B being the vertical projection, and the part below A B the horizontal projection; 3rd, by parts of cylinders cut in gores, forming flat sides, which diminish in width, as in Fig. 84.

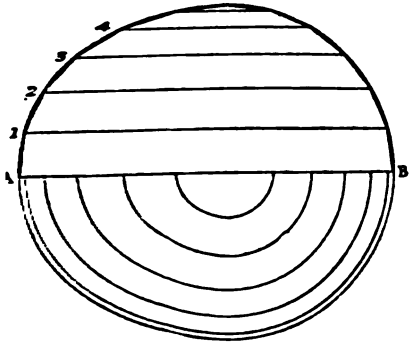


Fig. 83.

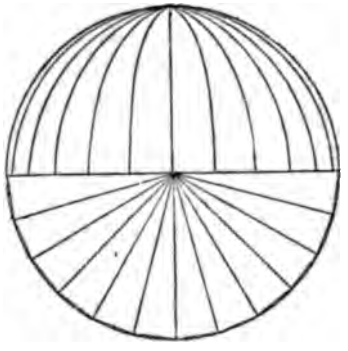


Fig. 84.

In reducing the spheres, or spheroid, to a polyhedron with flat sides, two methods may be adopted, which differ only in the manner of arranging the developed faces.

The most simple method is by parallel circles, and others perpendicular to them, which cut them in two opposite points, as in the lines on a terrestrial globe. If we suppose that these divisions, in place of being circles, are polygons of the same number of sides, there will result a polyhedron, like that represented in Fig. 82, of which the half, A D B, shows the geometrical elevation, and the other half, A E B, the plan.

To find the development, first obtain the summits

P, q, r, s, of the truncated pyramids, which from the demi-polyhedron A D B, by producing the sides A 1, 12, 23, 34, until they meet the axis E D produced; then from the points p, q, r, s, and with the radii P A, P I, q I q 2, r 2, r 3, and s 3, s 4, describe the indefinite arcs A B, 1 b, 1 b, 2 f, 2 f, e q, 3 g, 4 h, and from D describe the arc 4 h; upon all these arcs set off the divisions of the demi-polygons A E B, and draw the lines to the summits p, q, r, s, and D, from all the points so set out, as A, 1, 2, 3, 4, &c., from each truncated pyramid. These lines will represent for every band or zona the faces of the truncated pyramids of which they constitute a part.

The development can also be made by drawing through the centre of each side of the polygon A E B, indefinite perpendiculars, and setting out upon them the heights of the faces in the elevation, A1 2 3 4 D, and through the points thus obtained drawing parallels to the base. On each of these parallels then set out the widths, h, i, k, l, d, of the corresponding faces (e, e, e, &c.) in the plan, and there will be thus formed trapeziums and triangles, as in the first development, but arranged differently. This method is used in constructing geographical globes, the other is more convenient in finding the stones of a spherical dome.

The development of the sphere by reducing it to conical zones (Fig. 83) is accomplished in the same manner as the reduction to truncated pyramids, with this difference, that the developments of the arrises, indicated by A 1 2 3 4 5 B in Fig. 82, are arcs of circles described from the summits of cones, in place of being polygons.

The development of the sphere reduced into parts of cylinders, cut in gores (Fig. 84), is produced by the second method described, but in place of joining, by straight lines, the points E, h, i, k, l, d (Fig. 82), we

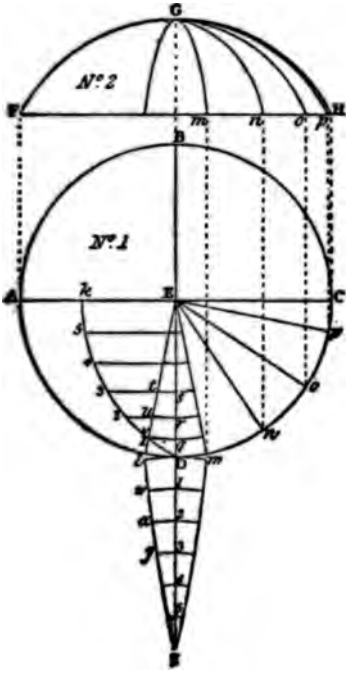


Fig. 85.

unite them by curves. This last method is used in tracing the development of caissons in spherical or spheroidal vaults.

To find the covering of a segmental dome.

In Fig. 85, No. 1 is the plan, and No. 2 the elevation of a segmental dome. Through the centre of the plan

E draw the diameter A C, and the diameter B D perpendicular to A C, and produce B D to I. Let D E represent the base of semi-section of the dome; upon D E describe the arc D k with the same radius as the arc F G H (No. 2); divide the arc D k into any number of equal parts, 1, 2, 3, 4, 5, and extend the division upon the right line D I, making the right line D I equal in length, and similar in its divisions, to the arc D k: from the points of division, 1, 2, 3, 4, 5, in the arc D k, draw lines perpendicular to D E, cutting it in the points q, r, s, &c. Upon the circumference of the plan No. 1, set off the breadth of the gores or boards l m, m n, n o, o p, &c.; and from the points l, m, n, o, p, draw right lines through the centre E: from E describe concentric arcs q v, r u, st, &c., and from l describe concentric arcs through the points D, 1, 2, 3, 4, 5,: l m, being the given breadth of the base, make l w equal to q v, 2x equal to r u, 3 y equal to st, &c.; draw the curved line through the points l, w, x, y, &c., to l, which will give one edge of the board or gore to coincide with the line l E. The other edge being similar, it will be found by making the distances from the centre line D 1 respectively equal. The seats of the different boards or gores on the elevation are found by the perpendicular dotted lines, pp, oo, nn, m m, &c.

To find the covering of a semicircular dome.

Fig. 86, Nos. 1 and 2.—The procedure here is more simple than in the case of the segmental dome, as the horizontal and vertical sections being alike, the ordinates are obtained at once.

› find the covering of a semicircular dome when it equired to cover the dome horizontally.

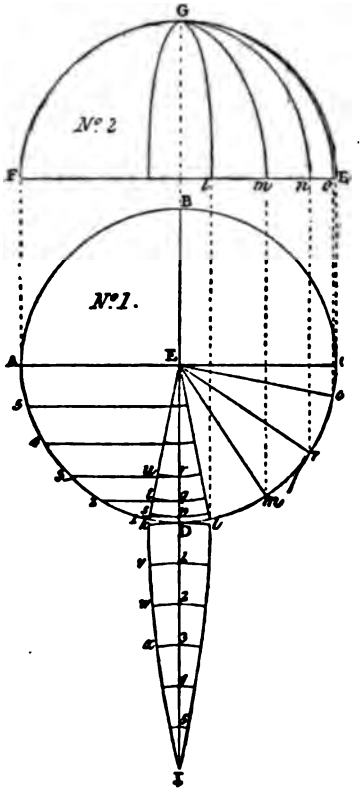


Fig. 86.

Let A B C (Fig. 87) be a vertical section through the is of a circular dome, and let it be required to cover is dome horizontally. Bisect the base in the point

D, and draw D B E perpendicular to A C, cutting the circumference in B. Now divide the arc B C into equal parts, so that each part will be rather less than

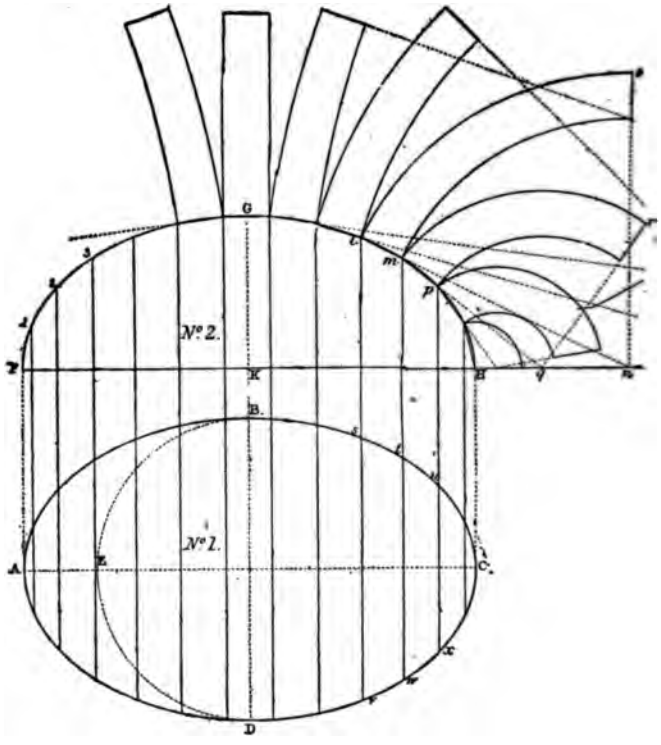


Fig. 87.

the width of the a board; and join the points division by straight lines, which will form an inscribed polygon of so many sides; and through these points draw line parallel to the base A C, meeting the opposite sides of

the circumference. The trapezoids formed by the sides of the polygon and the horizontal lines may then be regarded as the sections of so many frustums of cones; whence results the following mode of procedure, in

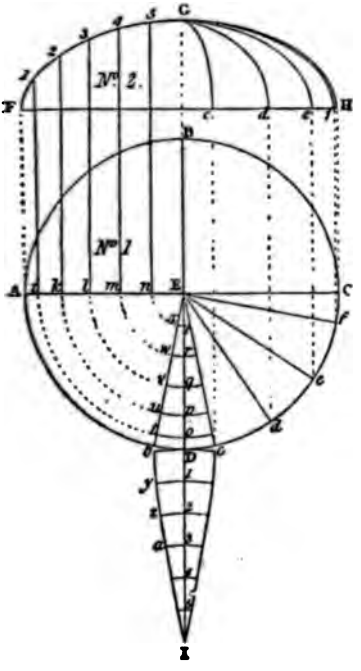


Fig. 88.

accordance with the introductory illustration Fig. 82; —Produce, until they meet the line D E, the lines g f, f, n, &c., forming the sides of the polygon. Then, to describe a board which corresponds to the surface of one of the zones, as f g, of which the trapezoid m l f g is a

section,—from the point h, where the line f g produced meets D E, with the radii h f, hg, describe two arcs, and cut off the end of the board k on the line of a radius h k.

To obtain the true length of the board, proceed as in Fig. 89. The other boards are described in the same manner.

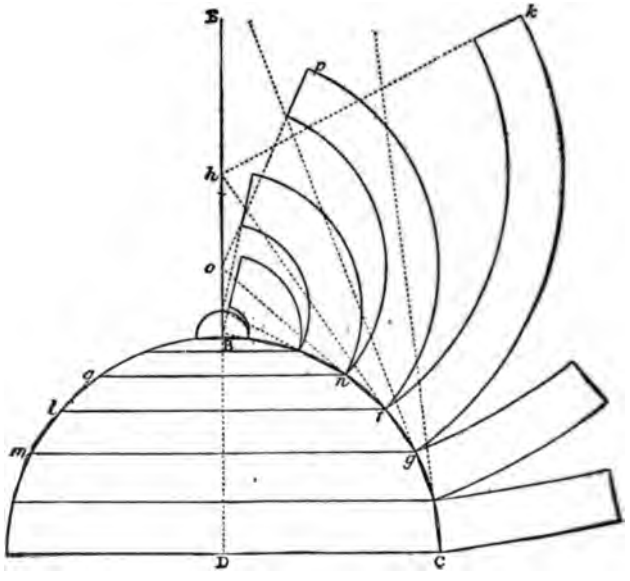


Fig. 89.

To find the covering of an elliptic dome.

Let A B C D (Fig. 90) be the plan, and F G H the elevation of the dome. Divide the elliptical quadrant F G (No. 2) into any number of equal parts in 1, 2, 3, 4, 5, and draw through the points of division lines

perpendicular to F H, and produced to A C (No. 1), meeting it in i, k, m, n,: these divisions are transferred by the dotted arcs to the gore b E c and the remainder of the process is as in Figs. 85 and 86.

To find the covering boards of an ellipsoidal dome.

Let A B C D (No. 1, Fig. 89) be the plan of the dome, and F G H (No. 2) the vertical section through its major axis. Produce F H indefinitely to n; divide the circumference, as before, into any number of equal parts, and join the divisions by straight lines, as p m, ml, &c. Then, describe on a board, produce the line forming one of the sides of the polygon, such as l m, to meet F n in n; and from n, with the radii n m, n l describe two arcs forming the sides of the board, and cut off the board on the line of the radius n o. Lines drawn through the points of divisions at right angles to the axis, until they meet the circumference A D C of the plan, will give the plan of the boarding.

To find the covering of an ellipsoidal dome in gores.

Let the ellipse A B C D (Fig. 90, No. 1) be the plan of the dome, A C its major axis and B D its minor axis; and let A B C (No. 2) be its elevation. Then, first, to describe on the plan and elevation the lines of the gores, proceed thus:—Through the line A C (No. 1) produced at H, draw the line E G perpendicular to it, and draw B E, D G, parallel to the axis A C, cutting E G, then will E G be the length of the axis minor, on which is to be described the semi-circle E F G, representing a section of the dome on a vertical plane passing through the axis minor.

Divide the circumference of the semi-circle into any number of equal parts, representing the widths of the

covering boards on the line B D; and through the points of division 1, 2, 3, 4, 5, draw lines parallel to the axis A C, cutting the line B D in 1, 2, 3, 4, 5. Divide the quadrant of the ellipse C D (No. 1) into any number of equal parts in e, f, g, h, and through these points draw the lines e a, f b, g c, h d in both diagrams, per-

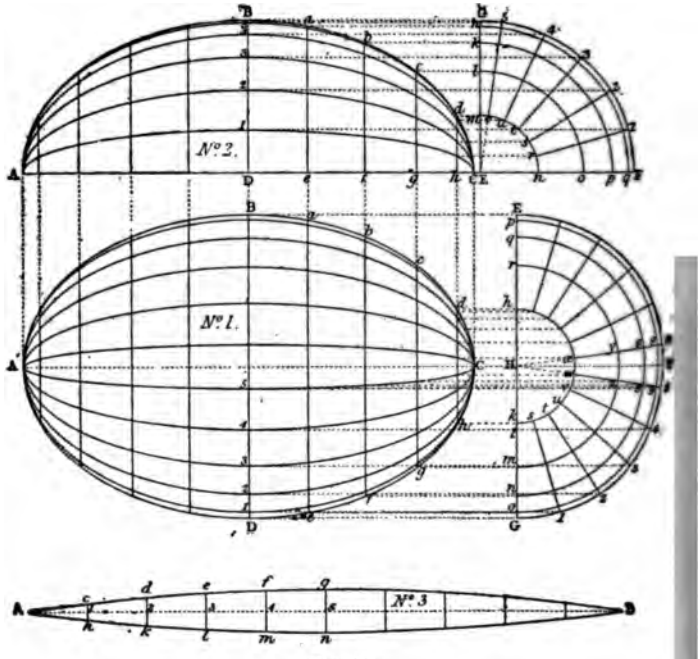


Fig. 90.

pendicular to A C, and these lines will then be the seats of vertical sections through the dome, parallel to E F G. Through the points e, f, g, h (No. 1) draw lines parallel to the axis A C, cutting E G in o, n, m, k;

and from H, with the radii H o, H n, H m, H k, describe concentric circles o 9 9 p, n 8 8q, m z y r, &c. To find the diminished width of each gore at the sections a, e, b f, c g, d h:—Through the divisions of the semi-circle, 1, 2, 3, 4, 5, draw the radii ls, 2t, 3u, 4v, 5w, 6x; then by drawing through the intersections of these radii with the concentric circles, lines parallel to H F, to meet the section lines corresponding to the circles, the width of the gores at each section will be obtained; and curves through these points will give the representation of the lines of the gores of the plan.

In No. 2 the intersections of the lines are more clearly shown. The quadrant E G F is half the end elevation of the dome, and is divided as in No. 1. The parallel lines 5 5, 4 4, 3 3, show how the divisions of the arc of the quadrant are transferred to the line D B, and the other parallels a h, b k, c l, d m, are drawn from the divisions in the circumference of the ellipse to the line E G, and give the radii of the arcs m, l o, k p, h q.

To describe one of the gores draw any line A B (No. 3), and make it equal in length to the circumference of the semi-ellipse A D C, by setting out on it the divisions 1, 2, 3, 4, 5, &c., corresponding to the divisions C h, h g, g f, &c., of the ellipse: draw through those divisions lines perpendicular to A B. Then from the semi-circle (No. 1) transfer to these perpendiculars the widths 6 5 to g n, 9 9 to f m, 8 8 to e l, y z to d k, and x w to c h, and join A c, d d, d e, e f, f g, A h, h k, k l, l m, and m n,; which will give the boundary lines of one-half of the gore, and the other half is obtained in the same manner.

To describe the covering of an ellipsoidal dome with horizontal boards of equal width.

Let A B C D (No. 1, Fig. 91) be the plan of the dome, A B C (No. 2) the section on its major axis, and L M N the section on its minor axis. Draw the circumscribing parallelogram of the ellipse, namely, F G H K (No. 1), and its diagonals F H G K. In No. 2 divide the circumference into equal parts, 1, 2, 3, 4, representing the number of covering boards, and through the points of division draw lines 1 8, 2 7, &c., parallel to A C. Through the points of divisions draw 1 p, 2 t, 3 x, &c., perpendicular to A C, cutting the diagonals of the circumscribing parallelogram of the ellipse (No. 1), and meeting its major axis in p, t, x, &c. Complete the parallelograms, and inscribe ellipses therein corresponding to the lines of the covering. Produce the sides of the parallelograms to intersect the circumference of the section on the minor axis of the ellipse in 1, 2, 3, 4, and lines drawn through these parallel to L N, will give the representation of the covering boards in that section. To find the development of the covering, produce the axis D B, in No. 2, indefinitely. Join by a straight line the divisions 1 2 in the circumference, and produce the line indefinitely, making e k equal to e 2, and k g equal to 1 2; 1 2e k g will be the axis major of the ellipses of the covering 1 2 7 8. Join also the corresponding divisions in the circumference of the section on the minor axis, and produce the line 1 2 b to meet the axis produced; and the length of this line will be the semi-axis minor, e h, of the ellipse, 2 h k, while the width f h will be equal to the division 12 in N M L.

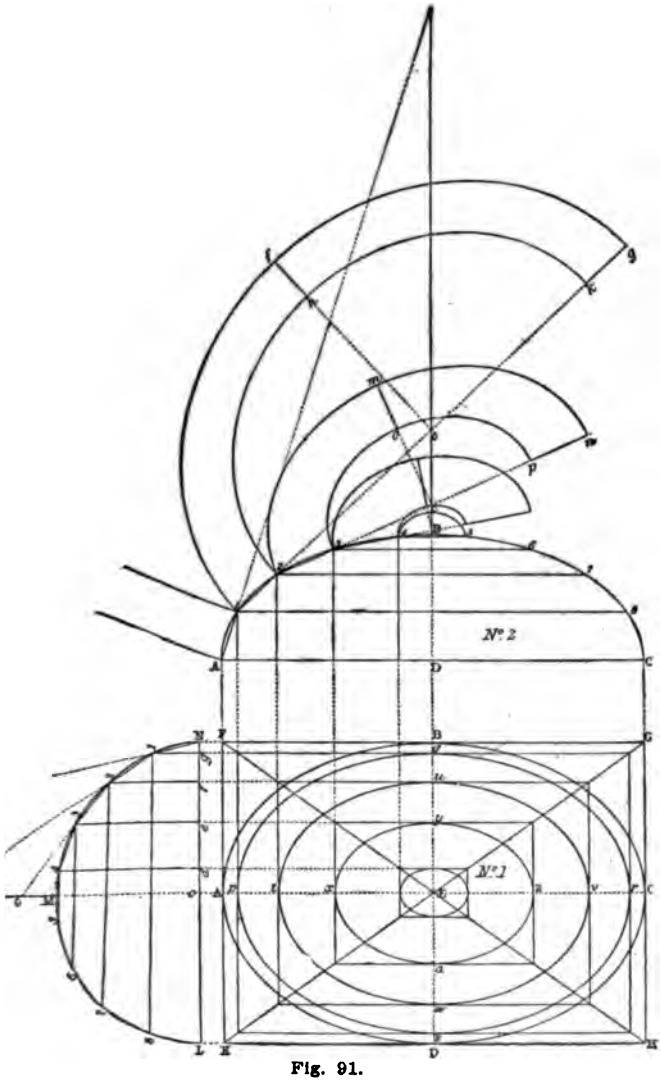


Fig. 91.

To find the covering of an annular vault.

Let A C K G E F A (Fig. 92) be the generating section of the vault. On A C describe a semi-circle A B C, and divide its circumference into equal parts, representing the boards of the covering. From the divisions of the semi-circle, b, m, t, &c., from the centre D of

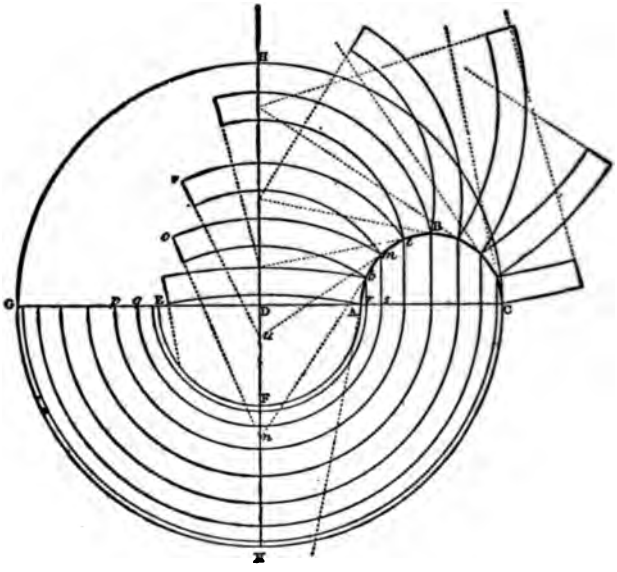


Fig. 92.

the annulus, with the radii D r, D s, &c., describe the concentric circles, s q, &c., representing the covering boards in plan. Through the centre D draw H K perpendicular to G C, indefinitely extending it through K. Join the points of division of the semi-circle, A b, b m, m t, by straight lines, and produce them until they cut

the line K H as m b n, t m u, when the points n, u, &c., are the centres from which the curves of the covering boards m o, t v, &c., are described.

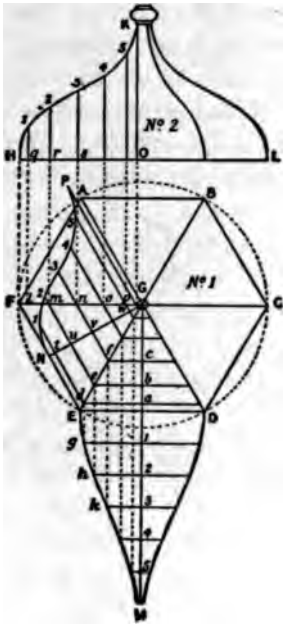


Fig. 93.

To find the covering of an ogee dome, hexagonal in plan.

Let A B C D E F (No. 1, Fig. 93) be the plan of the dome, and H K'L (No. 2) the elevation, on the diameter F C. Divide H K into any number of equal parts in 1, 2, 3, 4, 5, k, and through these draw perpendiculars to H L, and produce them to meet F C

(No. 1) in l, mm, n, o, p, G. Through these points draw lines l d, me, n f, &c., parallel to the side F E of the hexagon: bisect the side F E in N, and draw G N, which will be the seat of a section of the dome, at right angles to the side E F. To find this section nothing more is required than to set up on N G from the points t, u, v, &c., the heights of the corresponding ordinates q l, r 2, s 3, &c., of the elevation (No. 2) to draw the ogee curve N 1 2 3 4 5 p, and then to use the divisions in this curve to form the gore or covering of one side E g h k M D.

PART II.

PRACTICAL SOLUTIONS.

Having taken a thorough course in Solid Geometry, the student should be now prepared to solve almost any problem in practical construction, almost as soon as they present themselves. The various problems in construction, however, are so numerous, and in many cases, so intricate, that the student will often be confronted by problems which will require so many applications of the rules he has been taught, in different forms, that without some helping guidance, he will fail to see exactly what to do.

The following examples, with their explanations, are intended to give him the aid necessary to solve many difficult problems, and equip him with the means of still further investigation and sure results.

It is often necessary for the workman to find the exact stretchout or length of a straight line that shall equal the quadrant or a semi-circle.

To accomplish this:—Take A B radius, and A centre; intersect the circle at C; join it and B; draw from D, parallel with C B, cutting at H; then A H will be found equal to curve A D. Fig. 1.

This method is somewhat different to that already given; both, however, are practical.

Fig. 2. To find a straight line which is equal to the circumference of a circle. Draw from the centre, O,

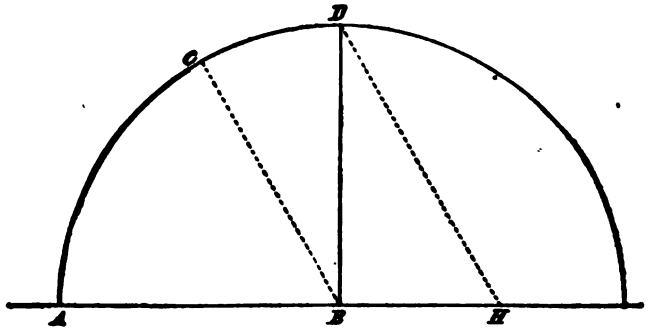


Fig. 1.

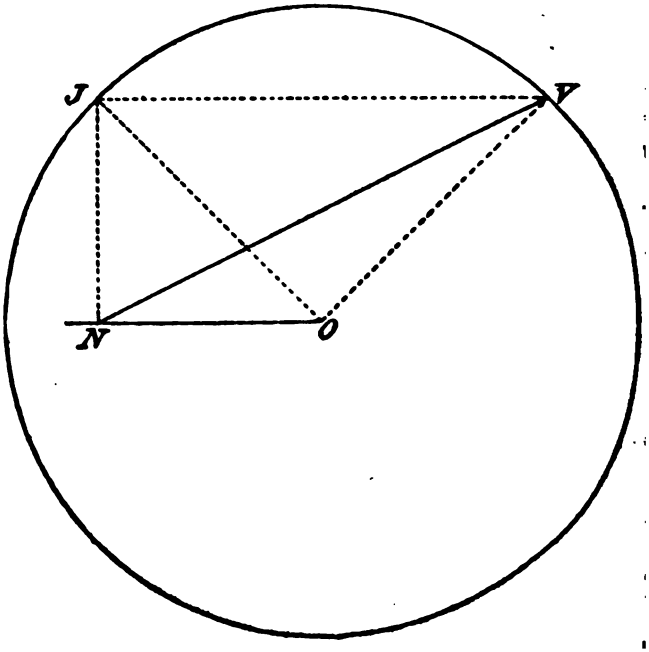


Fig. 2.

ght angle, cutting at J and V; join J V; draw O parallel with J V; square down from J, cut- t N; joint it and V; then four times N V will be to equal the circumference.

r to find the mitres for intersecting straight and ar mouldings.

ure 3 shows the form of an irregular piece of ng or other work, which requires to have mould- nitre and properly intersect.

usual way of doing this is to bisect each angle, lay two pieces of moulding against the sides of ng, and mark along the edge of each piece, thus ig an intersectic or. point, so that by drawing gh it to the next point, which is the angle of ng, the direction of mitre is obtained. This pro- however, is not the quickest and best by any s. The most simple and correct method is to ex- the sides A L and P H.

w suppose we wish to find a mitre from L; take centre, and with any radius, as K, draw the circle, ng at J; join it and K; draw from L parallel with and we have the mitre at once.

w come to angle on the right; here take H as e, and with any radius, as E, draw the circle, ng at F; join it and E; draw from H parallel with and you will find a correct mitre.

e next question is the intersection of straight and lar mouldings.

the present case an extreme curve is given, in to show the direction of mitre here, which is y on the principle of finding a centre, for three not on a straight line. For example, A B C are

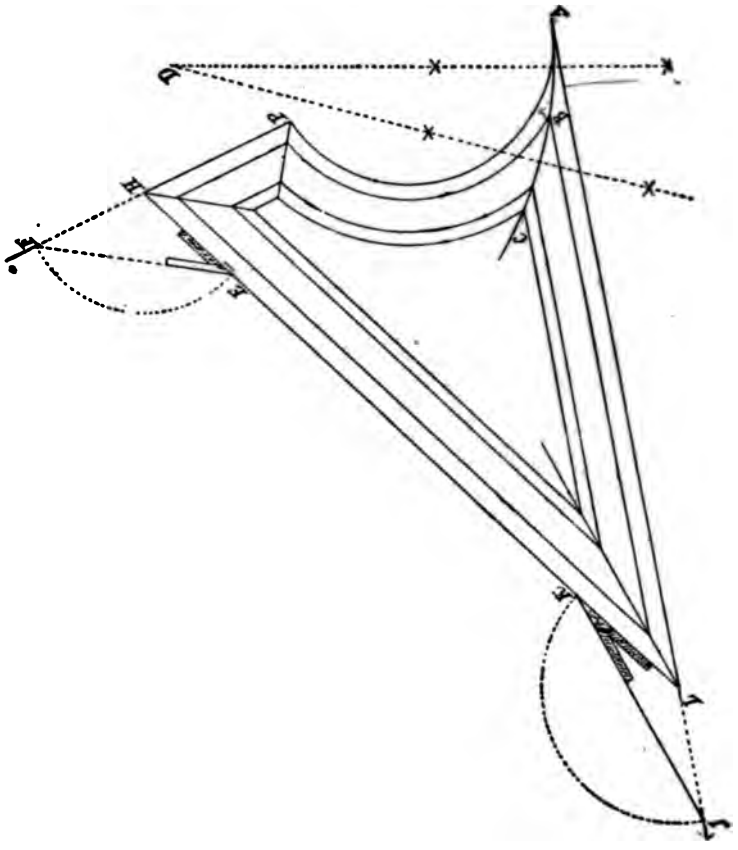


Fig. 3

points; bisect A B and B C; drawn through intersections thus made, and lines meeting in point D give a centre, from which strike the circular mitre as shown.

Here it may be stated that in some cases a straight line for mitres will answer; this means when the curve is a quadrant or less.

Fig. 4 shows the intersections of rake and level mouldings for pediments.

The moulding on the rake, increases in width, and is entirely different from that on the level, yet both mitre, and intersect, the rake moulding being worked to suit the level. If the curves of Fig. 4 are struck from centres as shown, then by the same rule, the rake moulding is also struck from centres.

Take any point in the curve, as C; square up from it, cutting at B; draw from C parallel to S L; join L K, which bisect at N; make E D equal to A B on the right; join L D and D N; bisect L D, also D N; draw through intersections thus made, and the lines meeting in F, give a point from which draw through N; make N J equal H F; then F and J are centres, from which strike the curve, and it will be found to exactly intersect with that of Fig. 4.

Both mouldings here are shown as solid, and of the same thickness. This is done for the purpose of making the drawing more plain and easily understood; but bear in mind that all crown mouldings are generally sprung.

To find the form of a sprung or solid moulding on any rake without the use of either ordinates or centres.

It may not be generally known, that if a level moulding is cut to a mitre, that the extreme parts of mitre,

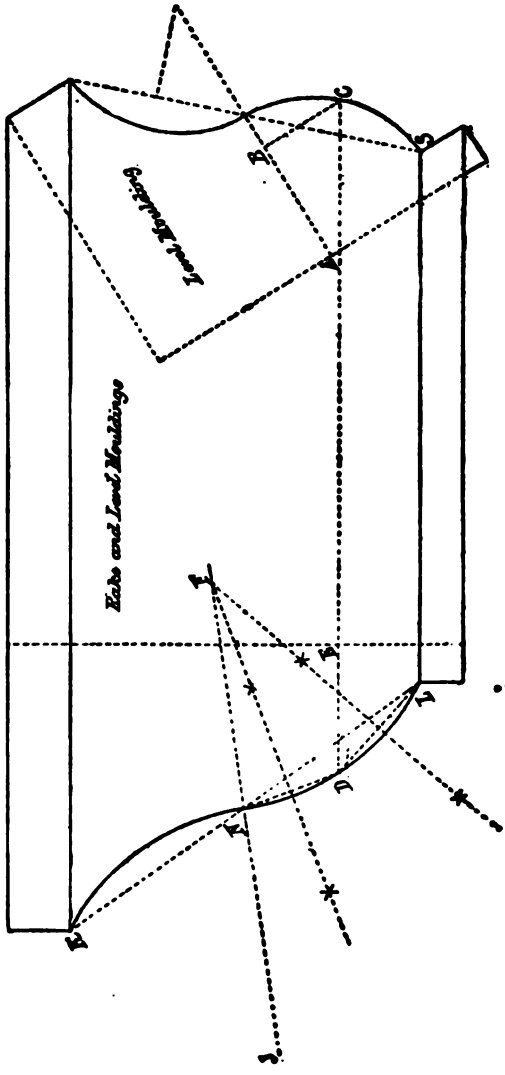


Fig. 4.

when in a certain position, will instantly give the exact form of a rake moulding, and it will intersect, and mitre correctly with that of level moulding. To do this, take the level piece which has been mitred; lay its flat surface on the drawing; make its point P at Fig. 5, stand opposite point P at Fig. 6; keep the outer edge fair with line N L. The piece being in this position, take a marker, hold it plumb against the mitre, and in this way, prick off any number of points as shown, through which trace the curve line, and the result is a correct pattern by which the rake moulding is worked.

A moment's consideration will convince us that this simple method must give the exact form of any rake moulding to intersect with one on the level.

To cut the mitres and dispense with the use of a box, this method will be found quick and off-hand. Take, for example, the back level moulding, and square over on its top edge any line, as that of F N; continue it across the back to H; make H V equal T L above, and from V, square over lower edge H K. Now take bevel 2 from above, and apply it on top edge, as shown; mark F L; then join L V; cut through these lines from the back, and the mitre is complete.

To cut the mitre on the rake moulding, square over any line on its back, as that of H J; continue it across the top and lower edge; take bevel X, shown above Fig. 5, apply it here on top edge, and mark D A; take the same bevel, and apply it on small square at E, and mark E 2.

We now want the plumb cut on lower edge J K, and the same cut on front edge N P, shown at Fig. 6. Take

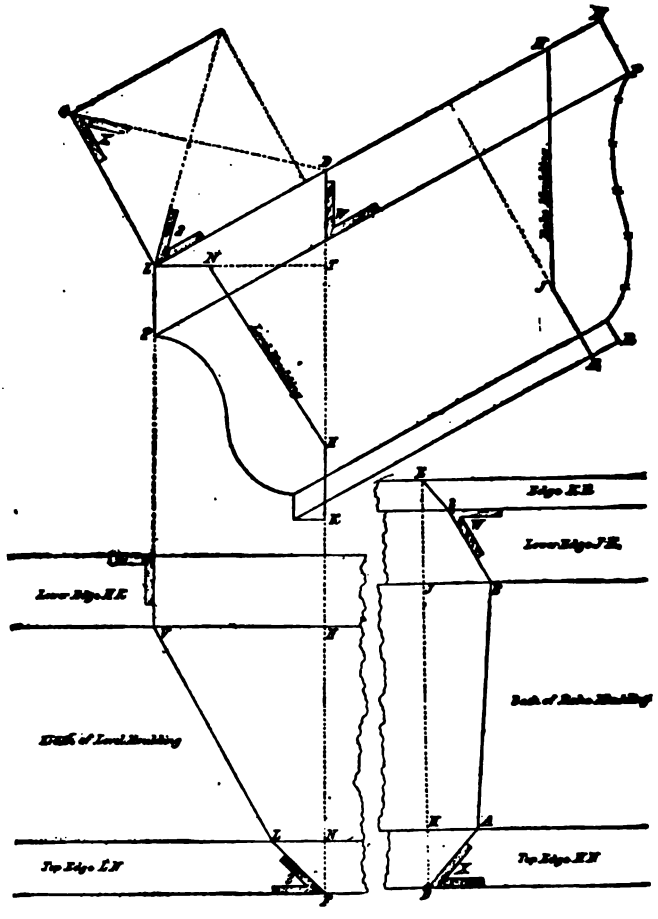


Fig. 5. Fig. 6.

bevel W above Fig. 5, apply it here and mark 2 B; join B A; this done, apply the same bevel on front edge N P, and mark the plumb cut, it being parallel with that of 2B here, or K J, Fig. 5; now cut through lines on the back, and the mitre is complete.

It has already been shown, that we dispense with making or using a box for mitreing sprung mouldings.

In this case, the front edge or upper member, stands parallel with face of wall, so that bevel X being appiled, gives the plumb cut; then the cut on top edge is square with face of wall. This shows, that we have only to find the direction of a cut on the back of moulding to make the mitre.

To do this, take any point as R; draw from it square with rake of gable. Now mark sections of moulding, as shown, its back parallel with R F; draw from D square with E N; extend the rake to cut line from D at K; this done, take any point on the rake, say L; draw from it parallel with R F, cutting at K; take it as centre and L as radius, and draw the arc of a circle with same radius return to K on the right; take it as centre, and draw the arc L H; make the first arc equal it; then draw from H parallel with L C, cutting at C J; draw from it square with rake, cutting at C, and join C K. This gives bevel W for cut on back of moulding.

A most perfect illustration of this may be had by having the drawing on card-board, and cutting it clear through all the outer lines, including that of the moulding on lines F D N E, making a hinge by a slight cut on line R F; also make a hinge of line R A, by a slight cut on the back, and in like manner make front edge

Fig. 9 shows the section of a square bar which has been cut by two unequal pitches, say in the direction of bevels J and H; the line C B is called the seat; from it all measurements are taken and transferred to lines that are square with the pitch A B; this pitch may be called a diameter, because it and the ordinate A E are at right angles.

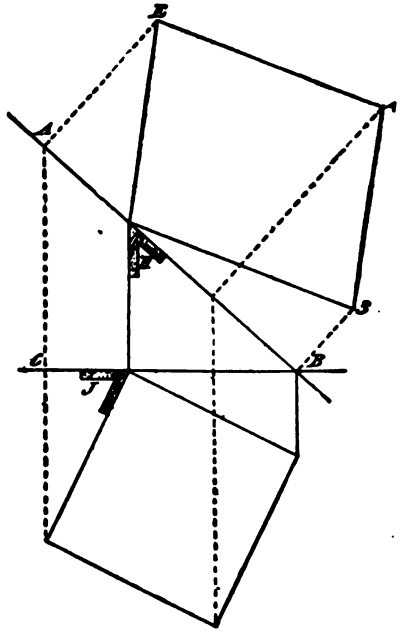


Fig. 9.

Fig. 10 shows the sides of a square bar which may be any length. The bar is to stand perpendicular, and pass through a plank that inclines at A B; the learner

on F D. Now bring mitres together, and we have a practical illustration of mitreing sprung mouldings on the rake. (See Fig. 7.)

PROJECTION OF SOLIDS.

The following illustrations will be found by the student almost indispensable in the construction of various objects, and they will open the door to many more.

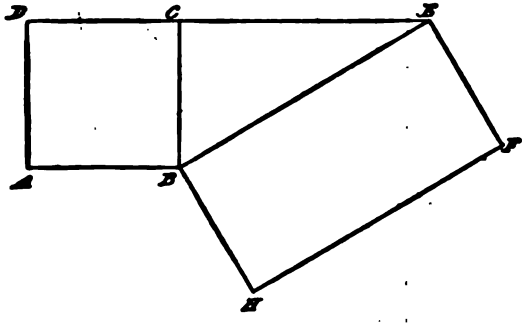


Fig. 8.

Fig. 8 shows the projection of a solid. This means the section of anything that is cut by a plane not parallel to its base; or, to put this in a more practical way—take a square bar of wood and cut it in the direction of B E; the section it makes is shown by B E F H; simple as this is, it still gives the idea of what is meant by projection.

Fig. 9 shows the section of a square bar which has been cut by two unequal pitches, say in the direction of bevels J and H; the line C B is called the seat; from it all measurements are taken and transferred to lines that are square with the pitch A B; this pitch may be called a diameter, because it and the ordinate A E are at right angles.

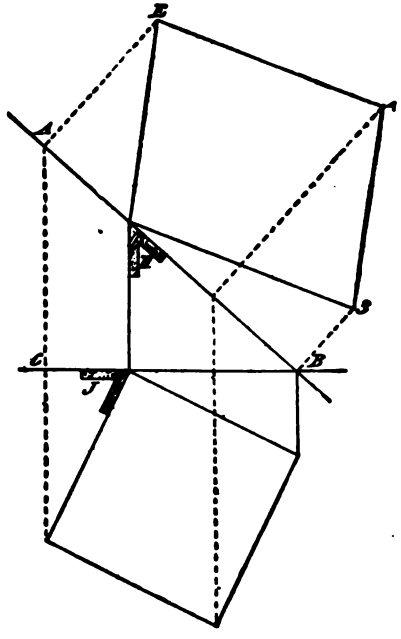


Fig. 9.

Fig. 10 shows the sides of a square bar which may be any length. The bar is to stand perpendicular, and pass through a plank that inclines at A B; the learner

; now required to show on the surface of plank the hape of a mortise that shall exactly fit the bar.

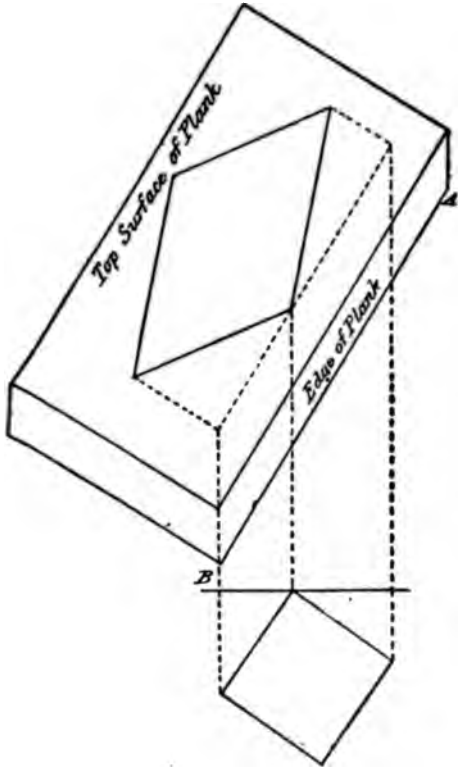


Fig. 10.

To solve this the student is left to exercise his own intelligence.

The problem may be clearly demonstrated by a card-board model; it being cut, and the parts pro-

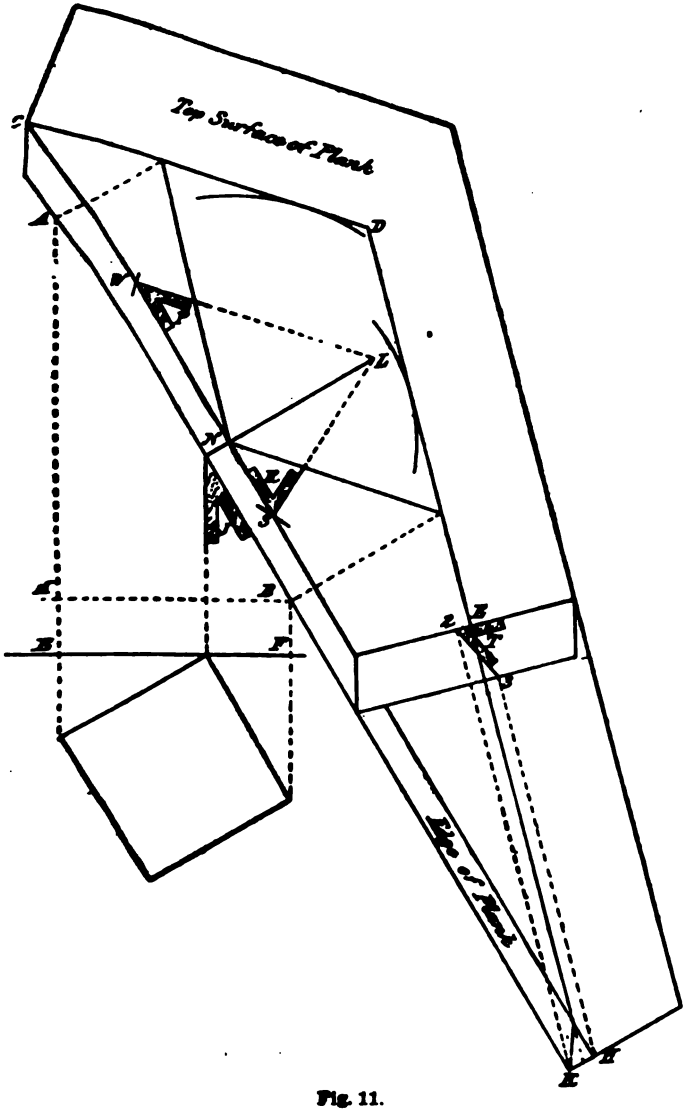
jected from the flat surface will represent the plank, and show the mortise in it standing directly over the square, Fig. 10.

Fig. 11. It is here required to mark two unequal pitches on two sides of a square bar—then to have a piece of plank or board cut so that it shall exactly fit both pitches on the bar. The inclination of plank may be assumed as A B, and height of both pitches as H A; let E F be the seat from which all measurements are taken, and transferred to lines that are on the surfaces of plank and square with A B; thus giving points to direct in drawing line C D; and D E produced.

Could we apply the bevel J to points C and K, and have plumb lines on the edge of plank, then by cutting through these and those already marked on the surface, the problem would at once be solved, by making both upper and under surface of plank fit the two pitches as required. But in practice this would be inadmissible on account of the great waste of material.

The proper method is to take any point, E, and cut through the plank square with E D, and at C, cut through the plank square with C D; here it will be noticed that line A D on the surface makes a very different pitch to that of A B on the edge of plank, and that C D differs from both.

To understand these points thoroughly is the true secret of the nicest element in the joiner's art—hand railing. It being clear that two bevels are required one for each pitch—proceed to find them. Make N L equal one side of the square. Take N as center, and strike an arc touching the line E D; with same radius, and L centre, make the intersection in S; join it at L,



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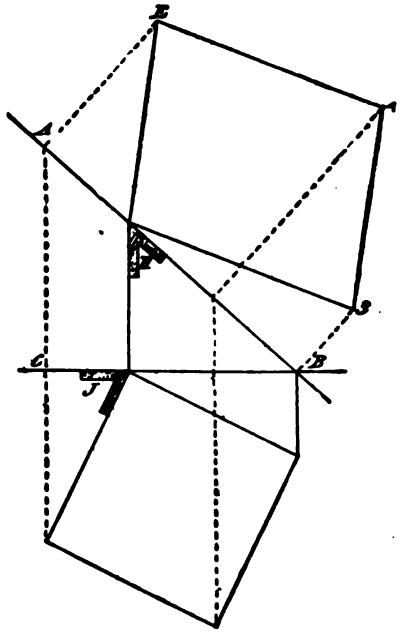

Fig. 9.

Fig. 10 shows the sides of a square bar which be any length. The bar is to stand perpendicular pass through a plank that inclines at A B; the le

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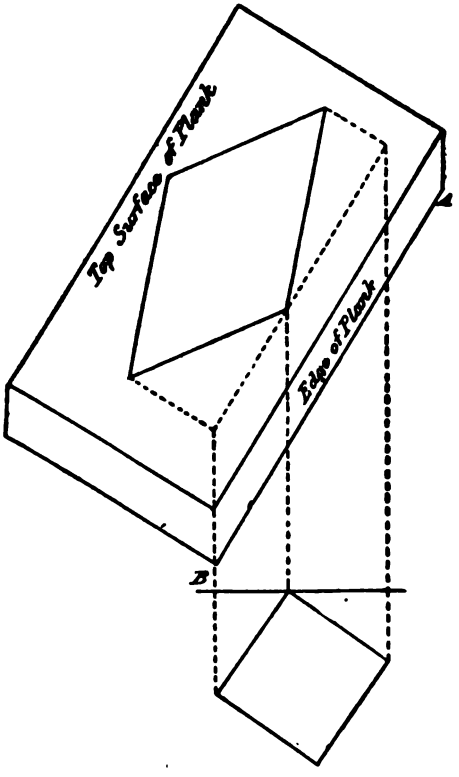


Fig. 10.

To solve this the student is left to exercise his own intelligence.

The problem may be clearly demonstrated by a card-board model; it being cut, and the parts pro-

as the sash, till they butt against the sill and bridle d and e, forming a triangular panel having for its base the cornice c, which is carried round the aperture horizontally, and finishing flush with the ceiling, permits the cornice on the corridor to be continued with-

Fig. 16.

out interruption. Observe in Fig. 16 the lower cornice finishes the walls, and the upper mouldings 0 marked c in Fig. 15 are carried round the well of the skylight.

Fig. 17 shows a plan of a panelled ceiling. The lower members or bed mouldings are carried round the walls of the room, and tend to build together, and give an

appearance of support to the several parts of the ceiling. The best way of making panelled ceilings is to cover the floor with boarding, and lay down the lines of the ceiling on the temporary floor thus formed. Then build and lath the ceiling on these lines. When it is completed it will be quite firm, and can be cut into sections suitable for being lifted up and attached to the joisting. The same lines will serve as guides for the plasterer setting the moulds for running the cornices and for preparing the circular ornament.

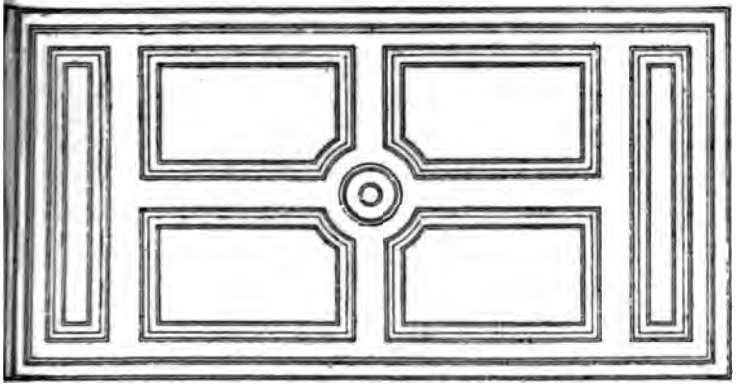


Fig. 17.

Fig. 18 shows in plan and section a centre suited for this ceiling. By fixing the central portion of it one inch from the surface of the finished ceiling and connecting it by small plaster blocks placed about one inch apart, it forms an excellent ventilator. A zinc tube can be led from this centre into a vent, and an

air tight valve put on the tube to prevent a down draft when the vent is not in use. F is an iron rod fixed to

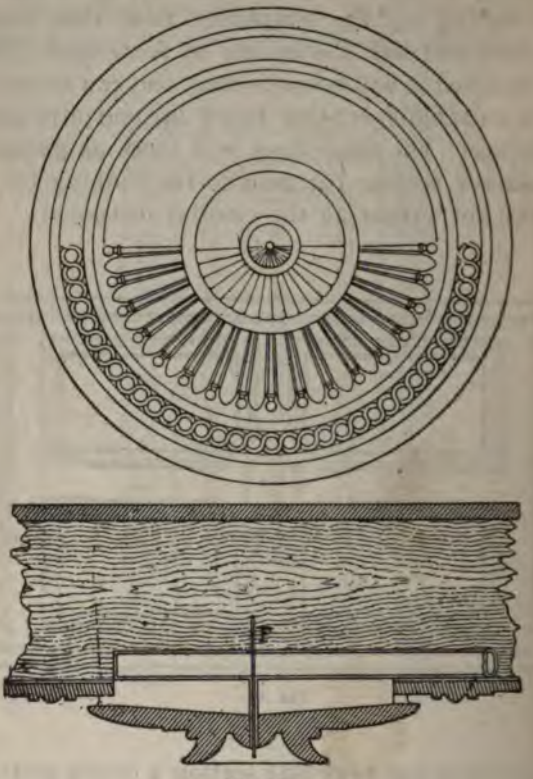


Fig. 18.

a strut or dwang between the joists for the purpose of securing a gas pendant or electrolier.

Let C A B (Fig. 19) be the elevation or the bracket of a core, to find the angle-bracket.

First, when it is a mitre-bracket in an interior angle, the angle being 45°: divide the curve C B into any

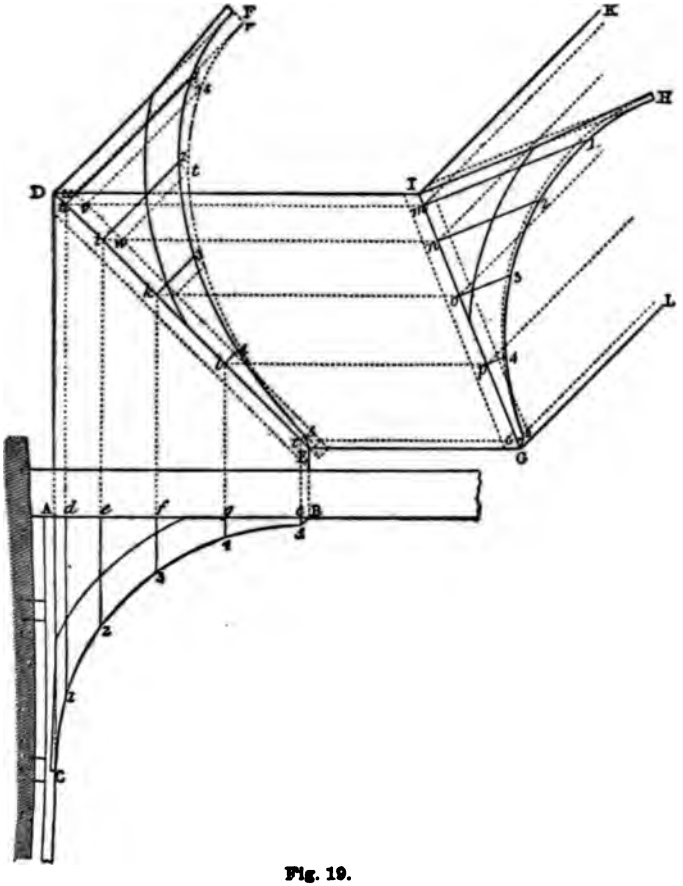


Fig. 19.

number of equal parts 1 2 3 4 5, and draw through the divisions the lines 1d, 2e, 3f, 4g, 5c, perpendicular to

A B, and cutting it in d e f g c; and produce them to meet the line D E, representing the centre of the seat of the angle-bracket: and from the points of intersection h i k l c draw lines h 1, i 2, k 3, l 4, at right angles to D E, and make them equal—h 1 to d 1, i 2 to e 2, &c.; and through F 1 2 3 4 5 draw the curve of the edge on the bracket. The dotted lines on each side of D E on the plan show the thickness of the bracket, and the dotted lines u r, v s w t, show the manner of finding the bevel of the face. In the same figure is shown the manner of finding the bracket for an obtuse exterior angle. Let D I K be the exterior angle: bisect it by the line I G, which will represent the seat of the centre of the bracket. The lines I H, m 1, n 2, o 3, p 4, c 5, are drawn perpendicular to I G, and their lengths are found as in the former case.

To find the angle-bracket of a cornice for interior and exterior, otherwise reentrant and salient, angles.

Let A A A (Fig. 20) be the elevation of the cornice-bracket, E B the seat of the mitre-bracket of the interior angle, and H G that of the mitre-bracket of the exterior angle. From the points A k a b c d A, or wherever a change in the form of the contour of the bracket occurs, draw lines perpendicular to A i or D C, cutting A i in e f g h i and cutting the line E B in E l m n o B. Draw the lines E G, G L B H, and H K, representing the plan of the bracketing, and the parallel lines from the intersection l m n o, as shown dotted in the engraving; then make B F and H I perpendicular to E B and G H respectively, and each equal to i A, o u to h d, n t to g c, m s to f b, l r to e a, l p to e k, and join the points so found to give the con-

tours of the brackets required. The bevels of the face are found as shown by the dotted lines x v y w, &c.

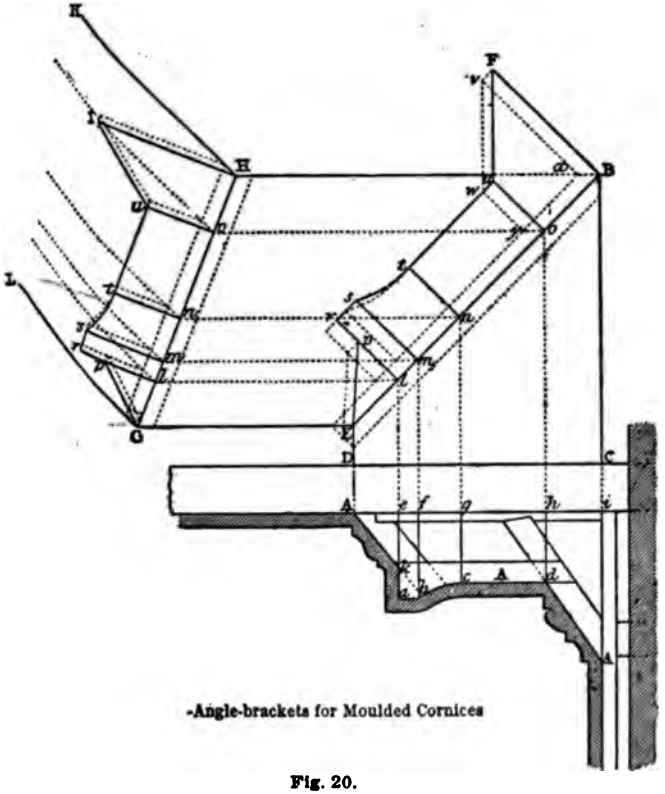


Fig. 20.

To find the angle-bracket at the meeting of a concave wall with a straight wall.

Let A D E B (Fig. 21) be the plan of the bracketing on the straight wall, and D M G E the plan on the cir-

cular wall, C A B the elevation on the straight wall, and G M H on the circular wall. Divide the curves

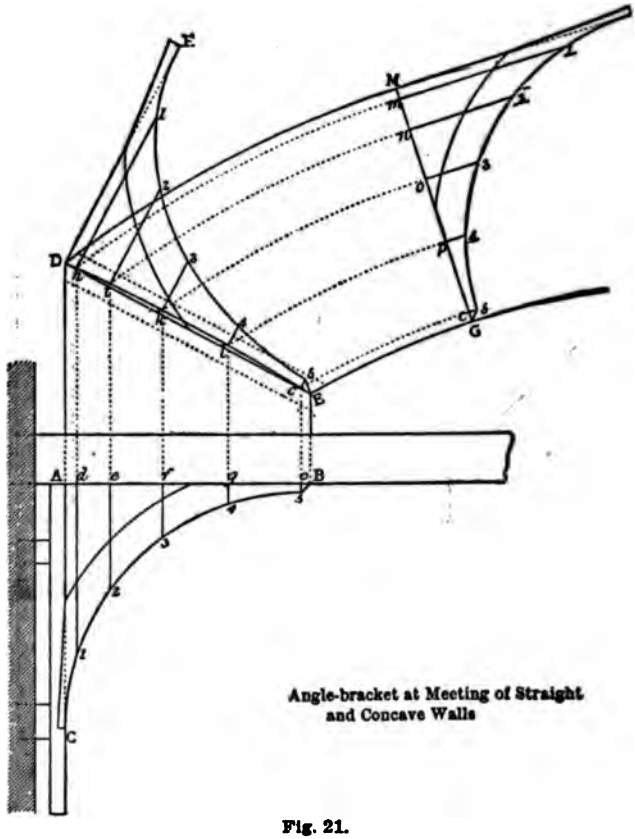


Fig. 21.

C B, G H into the same number of equal parts; through the divisions of C B draw the lines C D, 1 d h, 2 e i, &c., perpendicular to A B and through those of G H draw

the parellel lines, part straight and part curved 1 m h, 2 n i, 3 o k, &c. Then through the intersections h i k l of the straight end curved lines draw the curve D E, which will give the line from which to measure the ordinates h 1, i 2, k 3, &c.

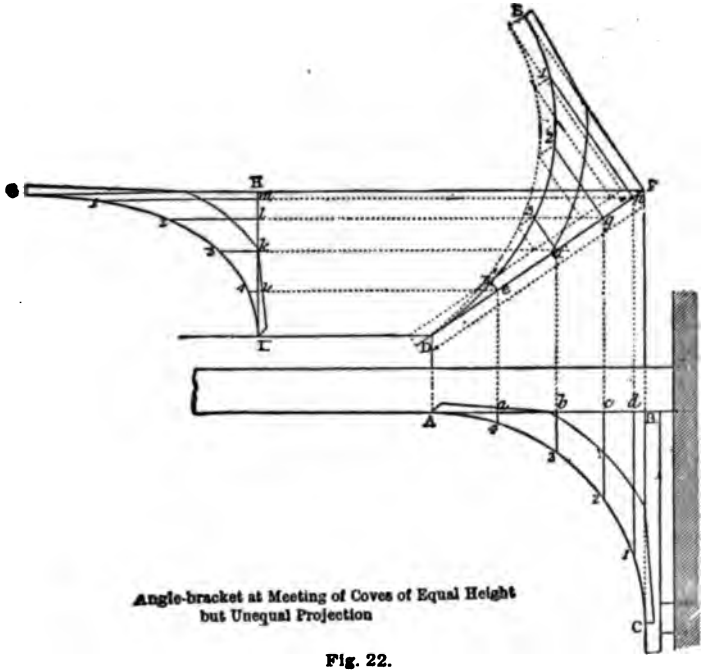
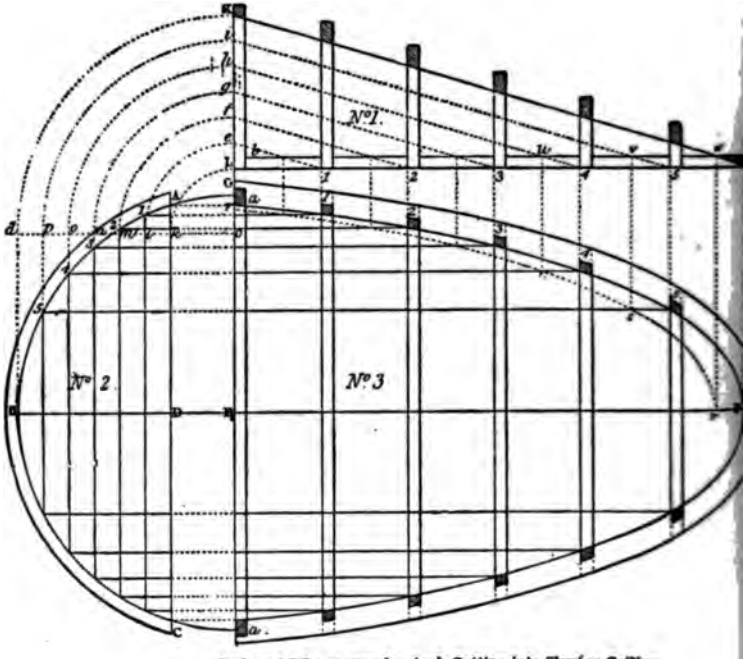


Fig. 22.

Fig. 22 shows the method of finding the angle-bracket at the meeting of coves of equal height but unequal projection. The height C B is equal to G H, but the projection B A is greater than H I.

Fig. 23, Nos. 1, 2, 3, shows the curb and ribs of a circular opening (C B A, No. 2), cutting in on a sloping ceiling. No. 1 is a section through the centre B D, No. 2 and E F I, No. 3. The height L K is divided into

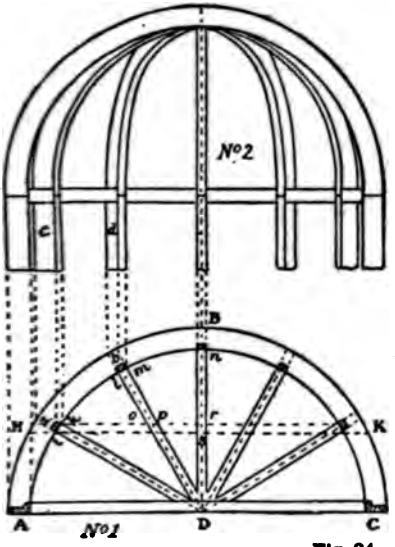


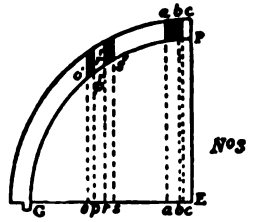
Curb and Ribs of Circular Arch Cutting into Sloping Ceiling

Fig. 23.

equal parts in e, f, g, h, i, and the same heights are transferred to the main rib in No. 2 at A, 1, 2, 3, 4, 5, B. Through the points A, 1, 2, 3, 4, 5, in No. 2 lines are drawn parallel to the axis B E I; and through the points e, f, g, h, i, in No. 1 lines are drawn parallel to

the slope K H. The places of the ribs 1, 2, 3, 4, 5, in the latter, and their site on the plan, No. 3, and also the curve of the curb, are found by intersecting lines in the manner with which the student is already acquainted.





Spherical Niches on Semicircular and Segmental Plans

Fig. 24.

ON NICHES.

To describe a spherical niche on a semi-circular plan. The construction of this (Fig. 24) is precisely like that of a spherical dome. The ribs stand in planes, which would pass through the axis if produced. They are all of similar curvature. No. 2 shows an elevation

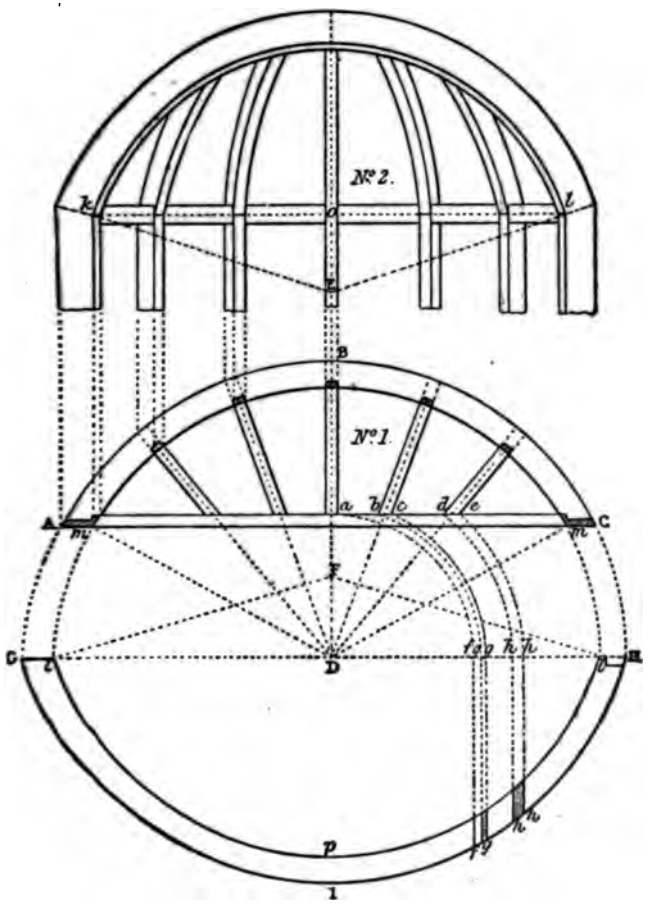
of the niche, and No. 3 the bevelling of the ribs a, b, against the front rib at D on the plan; a b is the bevel of a, and b c of b.

Let H B K (Fig. 24) be the plan. It is obvious that the ribs m p, n r, will be parts of the quadrant G F (No. 3). Transfer the lengths l o, m p, n r, and r s to the line G E, as shown at o p r s, and raise perpendiculars from these points to the quadrant; G p is the rib m p, and o p is the bevel; G r is the rib n r, and r s is the section of the front rib at the crown; the vertical projection of the upper arris of this rib will be a semi-circle with radius s s or s H.

The niche of which both the plan and elevation are segments of a circle.

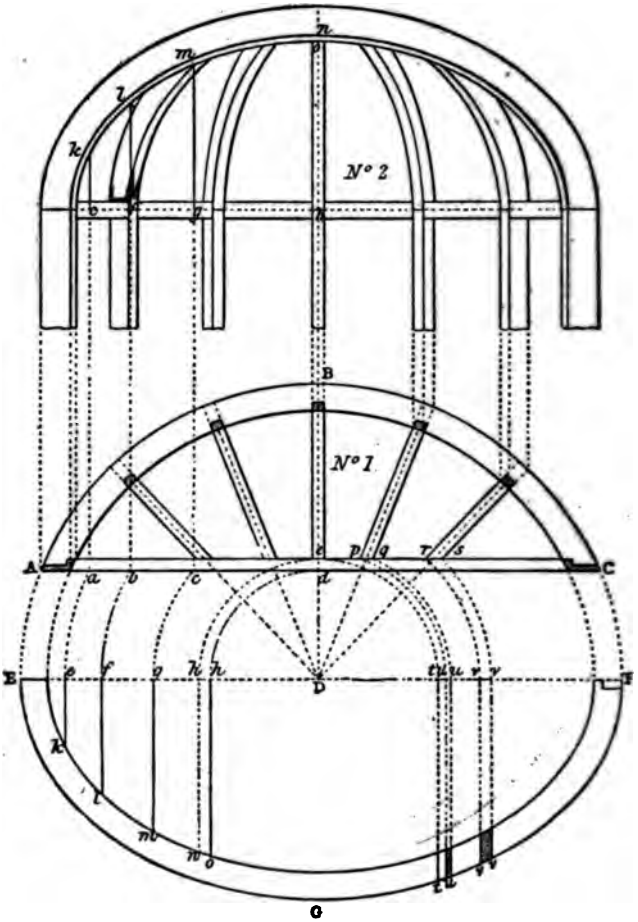
No. 25 is the elevation of the niche, being the segment of a circle whose centre is at E. No. 1, A B C, is the plan, which is a segment of a circle whose centre is D. Having drawn on the plan as many ribs as are required, radiating to centre D, and cutting the plan of the front rib in a, b c, d e; then through the centre D draw the line G H parallel to A C; and from D describe the curves m l, A G, C H, cutting the line G H; and make D F equal to E O, No. 2. From F as a centre describe the curves l p l and G I H for the depth of the ribs; and this is the true curve for all the back ribs.

To find the lengths and bevel of the ribs:—From the centre D describe the quadrant and arcs a f, b g, c g, d h, &c., and draw f f, g g, h h perpendicular to D H, cutting the curve l p l, and the lines of intersection will give the lengths and bevels of the several ribs.



-Segmental Niche on Segmental Plan

Fig. 25.



Elliptical Niche on Segmental Plan

Fig. 26.

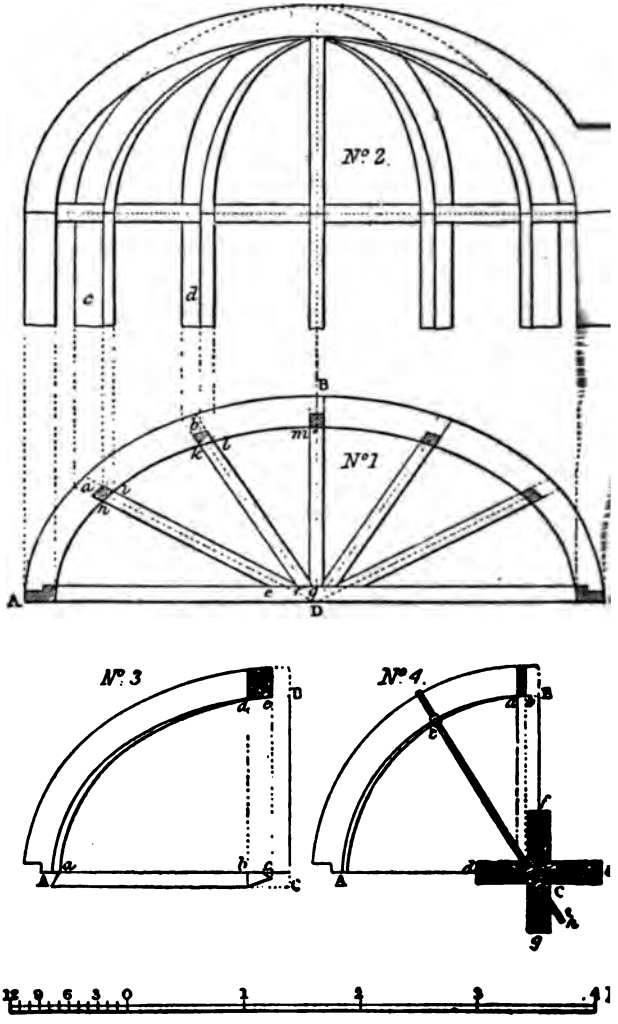
Let D in the plan (No. 1, Fig. 26) be the centre of the segment. Through D draw E F parallel to A C, and continue the curve of the segment to E F. Then to find the curve of the back ribs:—From k l m n, any points in the curve of the front rib (No. 2) let fall perpendicular to the line A B, cutting it in a b c d. Then from D as a centre describe the curves a e, b f, c g, e h, l h, and from the points where they meet the line E F draw the perpendiculars e k, f l, g m, h n, h o, and set up on e k the height ek of the elevation and the corresponding heights on their other ordinates, when l m n o will be the points through which the curve of the radial ribs may be traced. The manner of finding the lengths and bevels of the ribs is shown at u u v v.

A niche semi-elliptic in plan and elevation.

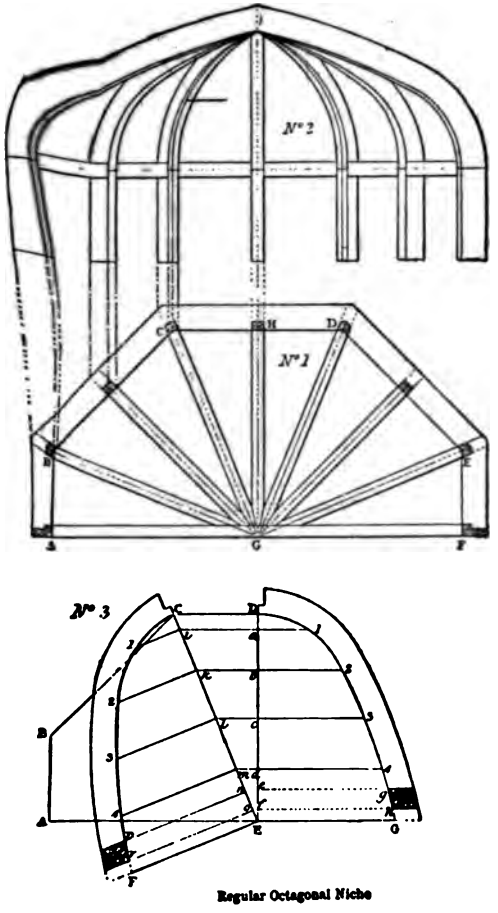
Let No. 1, Fig. 27, be the plan, and No. 2 the elevation of the niche. The ribs in this case radiate from the centre D, and with the exception of m g (which will be the quadrant of a circle) they are all portions of ellipses, and may be drawn by the trammel, as shown in No. 4, which gives the true curve of the rib marked d in No. 2 and b D in No. 1. The rib c, in the elevation, is seen at a D in No. 1; the bevel of the end h i is seen at A a in No. 3, and that of the end e f at b c.

To draw the ribs of a regular octagonal niche.

Fig. 28.—Let No. 1 be the plan, and No. 2 the elevation of the niche. It is obvious that the curve of the centre rib H G will be the same as that of either half of the front rib A G, F G. In No. 3, therefore, draw A B C D E, the half-plan of the niche, equal to A B C H G, No. 1, and make D G E equal to half the



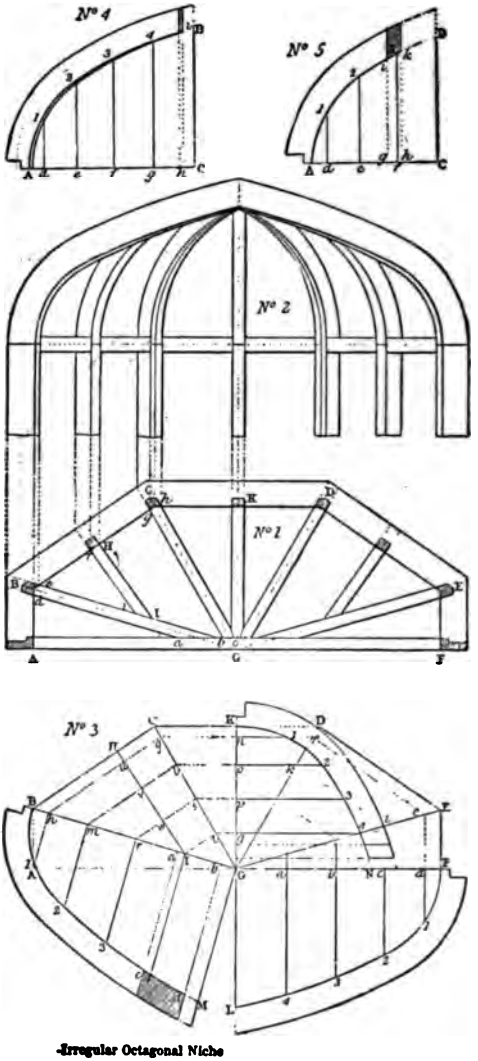
Elliptical Niche on Elliptical Plan
Fig. 27.



Regular Octagonal Niche

Fig. 28.

t rib. Divide D G into any number of parts 1 2 3 4, and through the points of division draw lines par- to A G, meeting the seat of the centre of the angle



Irregular Octagonal Niche

Fig. 29.

rib C E in i k l m n o. On these points raise indefinite perpendiculars, and set up on them the heights a l in i l, b 2 in k 2, and so on. The shaded parts show the bevel at the meeting of the ribs at G in No. 1.

To draw the ribs of an irregular octagonal niche.

Fig. 29.—Let No. 1 be the plan, and No. 2 the elevation of the niche. Draw the outline of the plan of the niche at A B C D E F (No. 3), and draw the centre lines of the seats of the ribs B G, H I, &c.; draw also G L F equal to the half of the front rib, as given in the elevation No. 2, and divide it into any number of parts 1 2 3 4. Through the points of division draw d l, c 2, b 3, a 4, perpendicular to G F, and produced to the seat of the first angle rib G E. Through the points of intersection draw lines parallel to the side E D of the niche meeting the second angle rib D G; through the points of intersection again draw parallels to D C, and so on. The curve of the centre rib is found by setting up from n o p q G the heights d 1, c 2, &c., on the parallel lines which are perpendicular to K G. The curve of the rib B G or E G is found by drawing through the points of intersection of the parallels perpendiculars to the seat of the rib, and setting upon them, at h m r I G, the heights d1, c2, &c. No. 4 shows the rib C G, and No. 5 the intermediate rib H I.

DOUBLE CURVATURE WORK.

To Obtain to Soffit Mould for marking the veneer (see Fig. 35), divide the elevation of lower edge of the head (Fig. 30) into a number of equal parts, as A, B, C, D, E, S, and drop projectors from these points into

the plan cutting the chord line A″ S″ in A″, B″, C″, D″, E″, S″. Draw the line s′ s′, Fig. 35, equal in length to the stretch out of the soffit in the elevation (the length of a curved line is transferred to a straight one by taking a series of small steps around it with the compasses, and repeating a like number of the straight line), and transfer the points A B C, &c., as they occur thereon, repeating them on each side of the centre line. Erect perpendiculars at the points, and make each of these lines equal in length to its correspondingly marked line in the plan, as A′ a′ a′ Fig. 35, equal to A″ a a Fig. 32, these letters referring respectively to the chord line and the inside and outside edges of the head. Draw the curves through the points so found. As will be seen by reference to Fig. 35, the mould is wider at the springing than at the crown; this is in consequence of the pulley stiles being parallel. If they were radial their width would be the same as the width of the head at the crown, and the head would be parallel; the gradual increase in width from the crown to the springing is also apparent in the sash-head and the beads, as indicated by the line O O, Fig. 35, which is the inside of the sash-head, and the outside of the parting head; this variation in width renders it impossible to gauge to a thickness from the face or the groove in the head from its edges.

To Form the Head. Having prepared the cylinder (Fig. 33) to the correct size, prepare a number of staves to the required section, which may be obtained by drawing one or two full size on the elevation, as shown to the right in Fig. 36. The staves should be dry straight-grained yellow deal, free from knots and

Fig. 30.

Fig. 31.

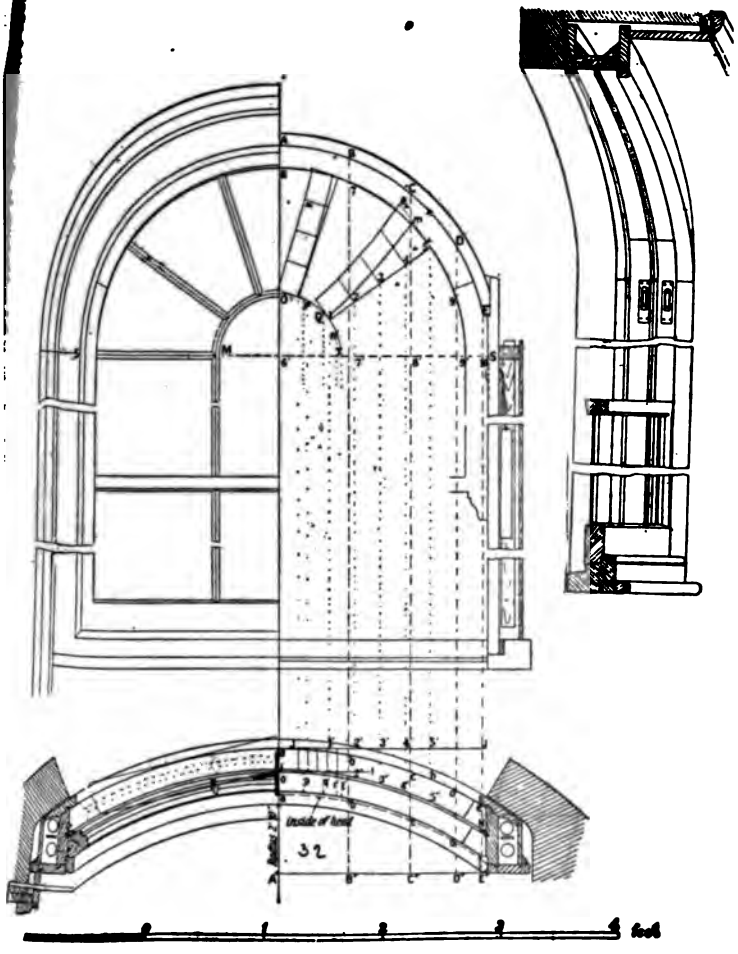


Fig. 32.

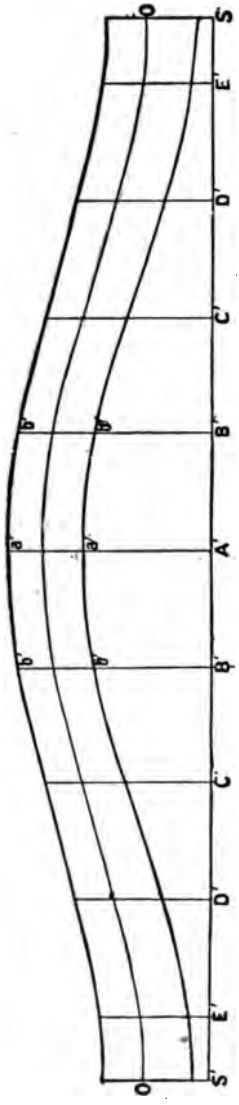


Fig. 35.

sap, and not be so wide
require hollowing to fit.
veneer is pine, it will prob
dry, but hardwood will req
ening with hot water.

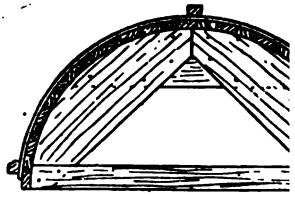


Fig. 33.

should be fixed as shown in
by screwing down a stave
Then the other end is be
over until the crown is

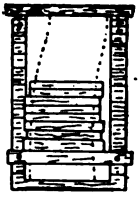


Fig. 34.

when another stave is scr
and the bending contin
the veneer is well down a
and a third stave secures
it is thoroughly dry, whe

mainder may be glued on. It is as well to interpose a sheet of paper between the cylinder and the veneer, in case any glue should run under, which would then adhere to the paper instead of the veneer. The head should not be worked for at least twelve hours after glueing. If a band saw is at hand, the back should be roughly cleaned off and the mould bent round it, the shape marked, and the edges can then be cut vertically with the saw, by sliding it over the cylinder sufficiently

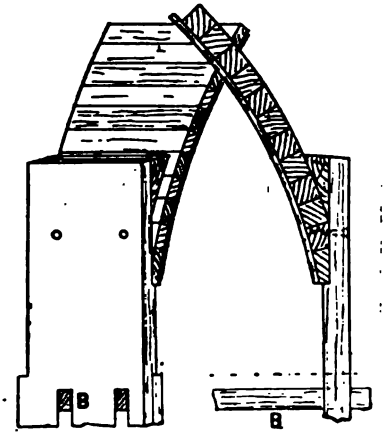


Fig. 36.

for the saw to pass. When cut by hand, the mould is applied inside and the cut is made square to the face, the proper bevel being obtained with the spokeshave, and found by standing the head over its plan and trying a set square against it. When fitting the head to the pulley stiles the correctness of the joints is tested by cutting a board to the same sweep as the sill, with

tenons at each end, and inserting it in the mortises for the pulleys, as shown at B, Fig. 36. A straight-edge applied to this and the sill will at once show if the head is in the correct position, and if the edges are vertical as they should be.

To Obtain a Developed Face Mould. Make the line i h, Fig. 37, equal to the stretch out of the plan of the face of sash-heads, viz., I H, Fig. 32. Transfer the divisions as they occur, and erect perpendiculars thereon.

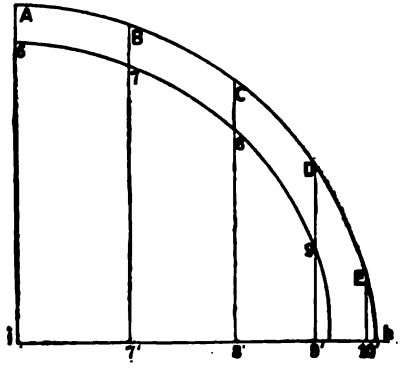


Fig. 37.

Make these equal in height to the corresponding ordinates over the springing line in the elevation, and draw the curves through the points so found. The groove for the parting bead can be marked by running a ⅜ in. piece around the inside of the sash-head, this bead being generally put in parallel. It is sometimes omitted altogether, the side beads being carried up until they die off on the head.

To Find the Mould for the Cot Bar. Divide its centre line in the elevation into equal parts, as O, P, Q, R, T. Drop projectors from these into the plan, cutting the chord line l l in o, p, q, r, t. These lines should be on the plan of the top sash, but are produced across the lower to avoid confusion with the projectors from the other bars. Set out the stretch out of the cot bar

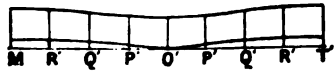


Fig. 38.

on the line M′ O′ T′, Fig. 38, and erect perpendiculars at the points of division, and make them equal in length to the correspondingly marked lines in the plan. The cot bar is cut out in one piece long enough to form the two upright sides as well as the arch. The straight parts are worked nearly to the springing, and the bar which is got out wider in the centre is then steamed and bent around a drum, and afterwards cut to the mould (Fig. 38) and then rebated and moulded. The arched bar should not be mortised for the radial bars, but the latter scribed over it and screwed through from inside.

To Find the Mould for the Radial Bars. Divide the centre line of the bar into equal parts, as 1, 2, 3, 4, 5, Fig. 30, and project the points into the plan, cutting the chord line J J in 1′, 2′, 3′, 4′, 5′. Erect perpendiculars upon the centre line from the points of division, and make them equal in length to the distance of the corresponding points in the plan from the chord line, and draw the curve through the points so obtained.

The other bar is treated in the same manner, the projectors being marked with full lines in the pla

Fig. 39.

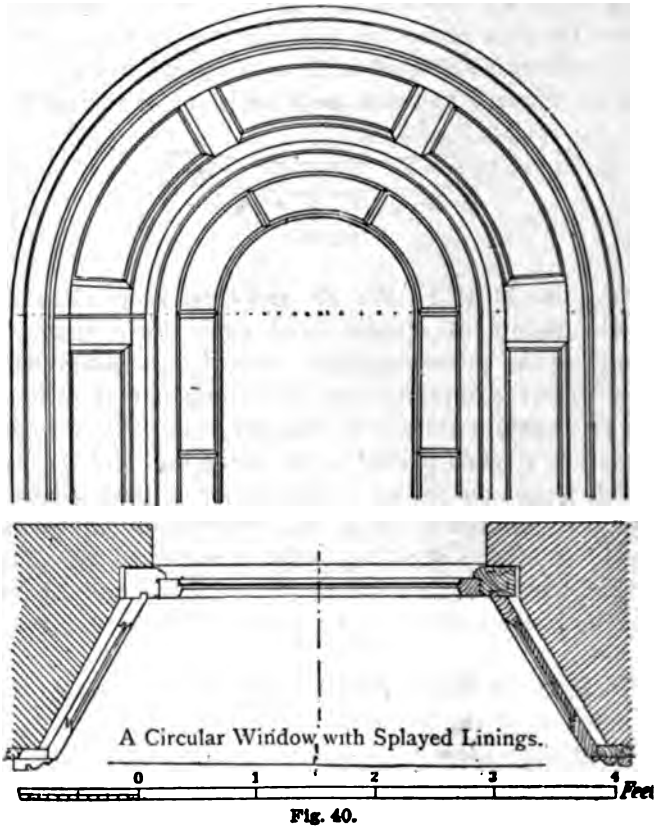


Fig. 40.

The soft moulds for the head linings are obtained in similar manner to those for the head mould, the width being gauged from the head itself

A Frame Splayed Lining with Circular Soffit as hown in part elevation in Fig. 39, plan Fig. 40, and ection Fig. 41. The soffit stiles are worked in the solid

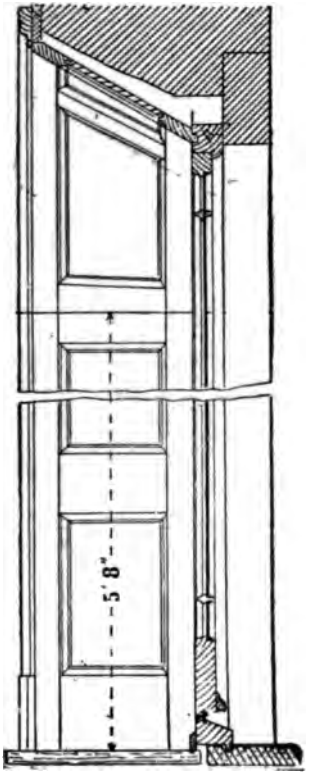
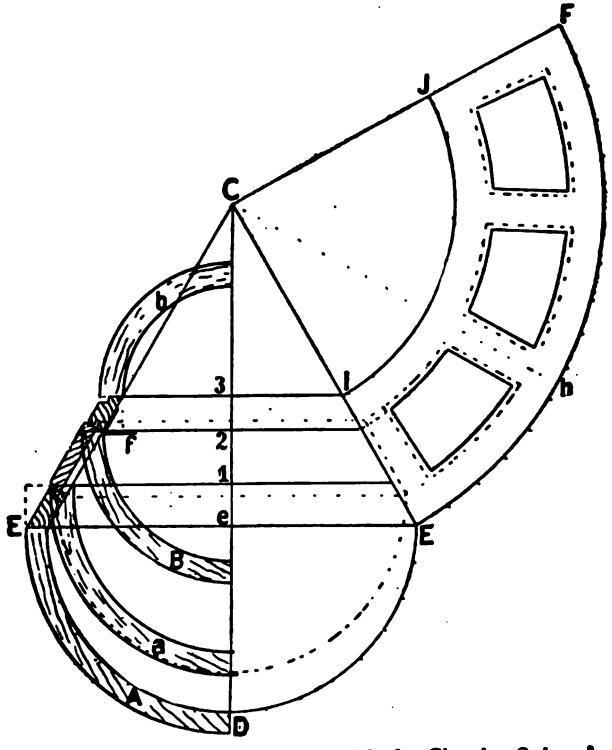


Fig. 41.

wo pieces joined at the crown and springings. The are worked with parallel edges, their centre lines ating from the centre of the elevation. Edge

moulds only are required for the stiles, and a develope mould for the panels. The method of obtaining the has been shown on a separate diagram, Fig. 42.



Method of Obtaining Moulds for Circular Splayed Linings.

Fig. 42.

To Obtain the Face Moulds for the Soffit Stile. Draw the line E E, Fig. 42, and produce the faces

the jambs until they meet in point C. From C draw the line C D perpendicularly to E E. This line will contain the centres of the various moulds, which are located by producing the plans of the edges of the stile across it e, 1, 2, 3 being the respective centres, and the inside and outside faces of the jambs affording the necessary radii for describing the arcs A a and B b.

To Apply the Moulds. Prepare the stuff equal in thickness to the distance between the lines e 1 and 2 3, Fig. 42. Apply the mould A to the face of the pieces intended for the front stile, and cut the ends to the mould, and square from the face. Set a bevel as at F, Fig. 42, and apply it on the squared ends, working from the lines on the face, and apply the mould a at the back, keeping its ends coincident with the joints, and at the points where the bevel lines intersect the face. The piece can then be cut and worked to these lines, and the inside edge squared from the face. The outside edge is at the correct bevel, and only requires squaring slightly on the back to form a seat for the grounds. The inside stile is marked and prepared similarly.

The Development of the Conical Surface of the Soffit is shown on the right hand of the diagram, Fig. 42, and is given to explain the method of obtaining the shape of the veneer, but it is not actually required in the present construction, as the panel being necessarily constructed on a cylinder, its true shape is defined thereon, and its size is readily obtained by marking direct from the soffit framing when the latter is put together. Let the semi-circle E D E, Fig. 42, represent a base of the semi-cone, and the triangle E C E its ver-

tical section. From the apex C, with the length of one of its sides as radius, described the arc E F, which make equal in length to the semi-circle E D E by stepping lengths as previously described. Join F to C, and E C F is the covering of the semi-cone. The shape of the frustum, or portion cut off by the section line of the linings, is found by projecting the inner edge of the lining upon the side C E, and drawing the con-

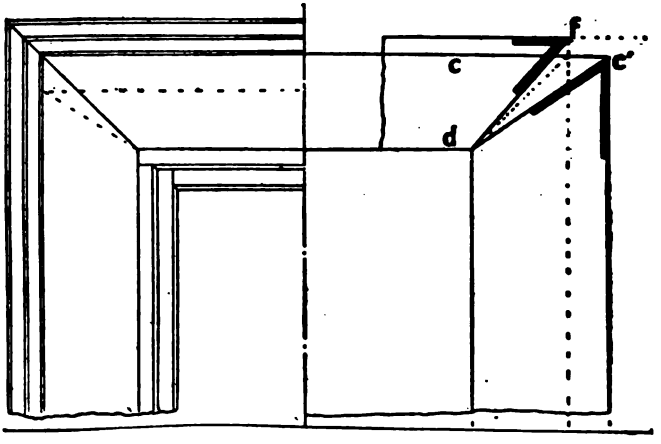


Fig. 43.

centric arc I J; then E I J E represents the covering of the frustum. Any portion of this, the panels for instance, is found in the same way. To draw the rails, divide their centre lines equally on the perimeter, and draw lines from the divisions to the centre as H C; make the edges parallel with these lines.

A Window With a Splayed Soffit and Splayed Jambs is shown in part elevation, Fig. 43, plan Fig. 44; and

section Fig. 45. The linings are grooved and tongued together, as shown in the enlarged section, Fig. 46. To obtain the correct bevel required for the shoulder of the jamb and the groove in the soffit, the lining must

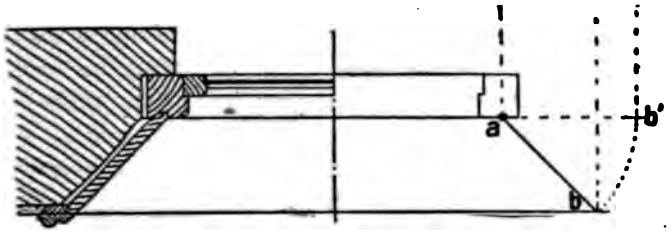


Fig. 44.

be revolved upon one of its edges until it is parallel with the front, when its real shape can be seen. This operation is shown in the diagram on the right-hand

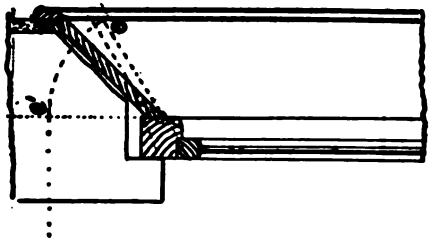


Fig. 45.

half of the plan and elevation. Draw the line a b, representing the face of the jamb in plan, at the desired angle. Project the edges into the elevation, and intersect them by lines c d, projected from the top and bottom edges of the soffit in section. This will give the projection of the linings in elevation. Then from point

a as centre, and the width of the lining a b as rad describe the arc b b′, bringing the edge b into same plane as the edge a. Project point b′ into elevation, cutting the top edge of the soffit produce c′. Draw a line from c′ to d, and the contained a is the bevel for the top of the jamb. When the i is splayed at the same angle as the jambs, the s bevel will answer for both; but when the angl different, as shown by the dotted lines at e, Fig. then the soffit also must be turned into the ver plane, as shown at e′ and a line drawn from that p to intersect the projection of the front edge of jamb in F; join this point to the intersection of lower edges, and the contained angle is the bevel the grooves in the soffit. (See Fig. 46.)

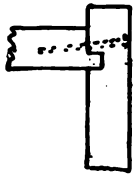


Fig. 46.

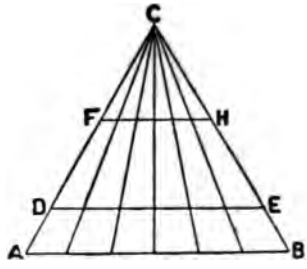


Fig. 47.

The Enlarging and Diminishing of Mouldings. design of a moulding can be readily enlarged to desired dimensions by drawing parallel lines from members, and laying a strip of paper or a straight-e of the required dimensions in an inclined direction tween the boundary lines of the top and bottom ed

and at the points where the straight-edge crosses the various lines, make marks thereon which will be points in the new projection, each member being increased proportionately to the whole. Projections drawn at right angles to the former from the same points will give data for increasing the width in like manner.

To Diminish a Moulding. The method to be explained, which is equally applicable to enlargement, is based upon one of the properties of a triangle, viz., if one of the sides of a triangle is divided into any number of parts, and lines drawn from the divisions to the opposite side of the triangle, any line parallel with the divided side will be divided in corresponding ratio. See Fig. 47, where A B C is an equilateral triangle, the side A B being divided into six equal parts, and lines drawn from these to the apex C. The two lines D E and F H, parallel to A B, are divided into the same number of parts, and each of these parts bears the same ratio to the whole line that the corresponding part bears to A B, viz., one-sixth; the application of this principle will now be shown. Let it be required to reduce the cornice shown in Fig. 48 to a similar one of smaller proportions. Draw parallel projectors from the various members to the back line A B, and upon this line describe an equilateral triangle. Draw lines from the points on the base to the apex, then set off upon one of the sides of the triangle from C a length equal to the desired height of the new cornice as at G or H, and from this point draw a line parallel to the base line. At the points where this line intersects the inclined division lines, draw horizontal projectors corresponding to the originals. To obtain their length

or amount of projection, draw the horizontal line b E, Fig. 48, at the level of the lowest member of the cornice, and upon this line drop projectors at right angles to it from the various members. Describe the equilateral triangle b i E upon this side, and draw lines from the divisions to the apex i. To ascertain the length

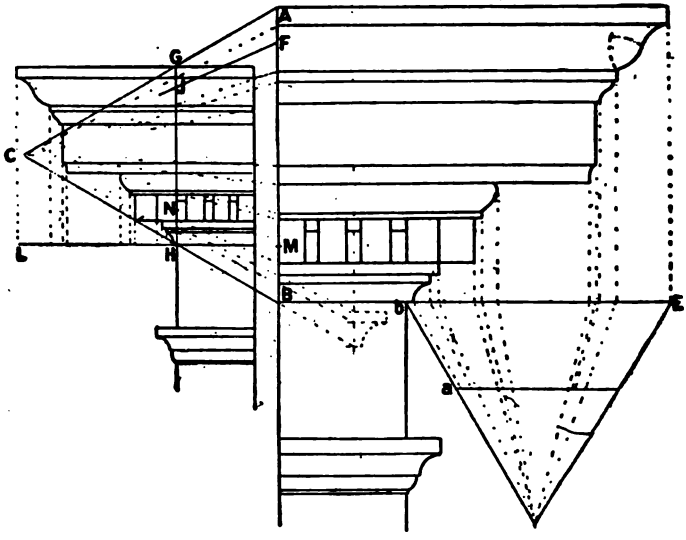


Fig. 49. Fig. 48.

that shall bear the same proportion to b E that the line G H bears to A B, place the length of b E on the line B A from B to F, and draw a line from F to C: the portion of the line G H cut off from J to H is the proportionate length required. Set this length off parallel to b E within the triangle, as before described, and also draw the horizontal line L H, Fig. 49, making it

equal in length to a a, Fig. 48. Upon this line set off the divisions as they occur on a a, noting that their direction is reversed in the two figures. Erect perpendiculars from these points to intersect the previously drawn horizontals, and through the intersections trace the new profile. The frieze and architrave are reduced in like manner, M B, Fig. 48, representing the height of the original architrave, and N H the reduction. The cornice can be enlarged similarly by pro-

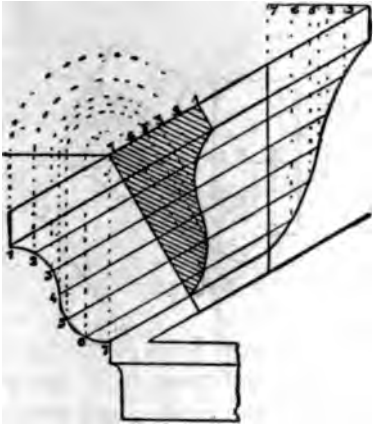


Fig. 50.

ducing the inclined sides of the triangle, as shown by the dotted lines on Fig. 48, sufficiently to enable the required depth to be drawn within it parallel to A B. One member has been enlarged to indicate the method, which should be clear without further explanation.

Raking Mouldings. Fig. 50 shows the method of finding the true section of an inclined moulding that is required to mitre with a similar horizontal moulding

at its lower end, as in pediments of doors and windows. The horizontal section being the more readily seen, is usually decided first. Let the profile in Fig. 50 represent this. Divide the outline into any number of parts, and erect perpendiculars therefrom, to cut a horizontal line drawn from the intersection of the back of the moulding with the top edge, as at point 7. With this point as a centre and the vertical projectors from 1 to 7 as radii, describe arcs cutting the top of the inclined mould, as shown. From these points draw perpendicu-

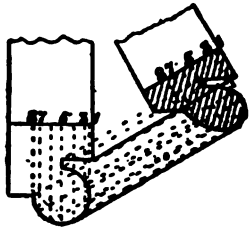


Fig. 51.

lars to the rake, to meet lines parallel to the edges of the inclined moulding drawn from the corresponding points of division in the profile, and their intersections will give points in the curve through which to draw the section of the raking mould. When the pediment is broken and a level moulding returned at the top, its section is found in a similar manner, as will be clear by inspection of the drawing. If the section of the raking moulding is given, that of the horizontal mould can be found by reversing the process described above. Fig. 51 shows the application of the method in finding the section of a return bead when one side is level and

the other inclined, as on the edge of the curb of a skylight with vertical ends.

Sprung Mouldings. Mouldings curved in either elevation or plan are called "sprung," and when these are used in a pediment, require the section to be determined as in a raking moulding. The operation is similar to that described above up to the point where the back of the section is drawn perpendicular to the inclination, but in the present case this line E x, Fig. 52.

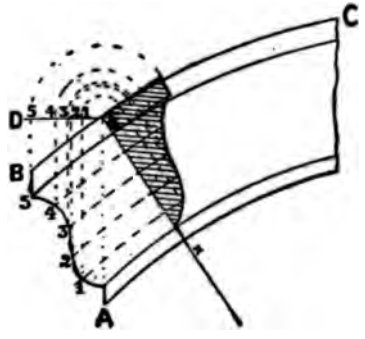


Fig. 52.

is drawn radiating from the centre of the curve, and the projectors are drawn parallel to this line. The parallel projectors, 1, 2, 3, 4, 5, are also described from the centre until they reach the line E x, when perpendiculars to this line are raised from the points of intersection to meet the perpendicular projectors.

Mitreing Straight and Curved Mouldings Together. If a straight mitre is required, draw the plan of the mouldings, as in Fig. 53, and the section of the straight mould at right angles to its plan as at A. Divide its

profile into any number of parts, and from them draw parallels to the edges intersecting the mitre line. From these intersections describe arcs concentric with the plan of the curved mould, and at any convenient point thereon draw a line radial from the centre. Erect perpendiculars on this line from the points where the arcs intersect it, and make them equal in height to the corresponding lines on the section of the straight moulding A, and these will be points in the profile of

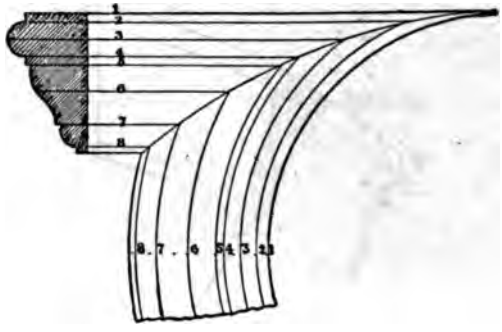


Fig. 53.

the curved moulding B. When it is required that the section of both mouldings shall be alike, a circular mitre is necessary, and its true shape is obtained as shown in Fig. 53. Draw the plan and divide the profile of the straight moulding as before, drawing parallels to the edge towards the seat of the mitre. Upon a line drawn through the centre of the curved moulding set off divisions equal and similar to those on the straight part, as 1 to 8 in the drawing. From the centre of the

curve describe arcs passing through these points, and through the points of intersection of these arcs with the parallel projectors, draw a curve which will be the true shape of the mitre. Cut a saddle templet to this shape, and use it to mark the mouldings and guide the chisel in cutting.

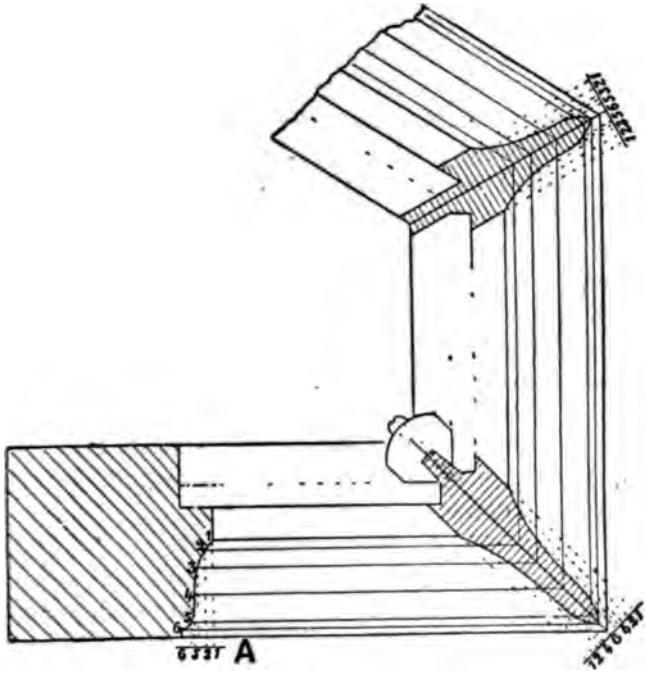


Fig. 54.

To Obtain the Section of a Sash Bar Raking in Plan. Fig. 54 represents the plan of a shop front sash with bars in the angles. On the left hand is shown the sec-

tion of the stile or rail into which the bars have to mitre. Divide the profile of moulding into a number of parts, as shown from 1 to 6, and from these points draw parallels to the sides of the rails intersecting the centre line of the bar. Also draw perpendiculars from the same ponts to any line at right angles to them, as at A. Draw a line at right angles to the centre line of the bar, and on it set off the divisions from 1 to 6 as at A. Draw projectors from these points parallel to the centre line of the bar, and where they intersect the correspondingly numbered lines drawn parallel with the sides of the sash will be points in the curve of the section of the bar. It will be noticed that there is no fillet or square shown on the bar, and that in transferring the points from the line A they must be reversed on each side of the centre. Should a fillet be required on the bar, additional thickness must be given for the purpose. Three methods of forming the rebates in the bar are shown, the screwed saddle beads being the best for securing the glass.

Interior Shutters Include Folding, Sliding, Balanced, and Rolling. Exterior Consist of Hanging, Lifting, Spring, and Venetian Shutters.

FOLDING, or as they are frequently called, BOXING SHUTTERS, because they fold into a boxing or recess formed between the window frames and the walls, are composed of a number of narrow leaves, framed or plain, as their size may determine, rebated and hinged to each other and to the window frames. They should be of such size that when opened out they will cover the entire light space of the sash frame and a margin of a ¼ in. in addition. Care must be taken

to make them parallel, or they will not swing clear at the ends; and as a further precaution, they should not be carried right from soffit to window board, but have clearance pieces interposed at their ends about ⅜ in. thick. The outer leaf, which is always framed, is termed a shutter; the others are termed flaps. It is not advisable to make the shutters less than 1¼ in. thick, and flaps over 8 in. wide should be framed; those less than 8 in. may be solid, but should be mitre clamped to prevent warping. In a superior class of work the boxings are provided with cover flaps which conceal the shutters when folded, and fill the void when they are opened out. The sizes and arrangements of the framing are determined by the general finishings of the apartment, but it is usual to make the stiles of the front shutters range with those of the soffit and elbow linings. When venetian or other blinds are used inside, provision is made for them by constructing a block frame from 2½ to 3 in. thick inside the window frame and the shutters are hung to this.

The leaves are hung to each other with wide hinges called back flaps, that screw on the face of the leaves, there not being sufficient surface on the edges for butt hinges. In setting out the depth of boxings, at least ⅛ in. should be allowed between each shutter to provide room for the fittings; the shutters are fastened by a flat iron bar hung on a pivot plate fixed on the inner left-hand leaf, and having a projecting stud at its other end which fits into a slotted plate, and it is kept in this position by a cam or button. Long shutters are made in two lengths, the joint coming opposite the meeting rails of the sashes; these are sometimes rebated together at the ends.

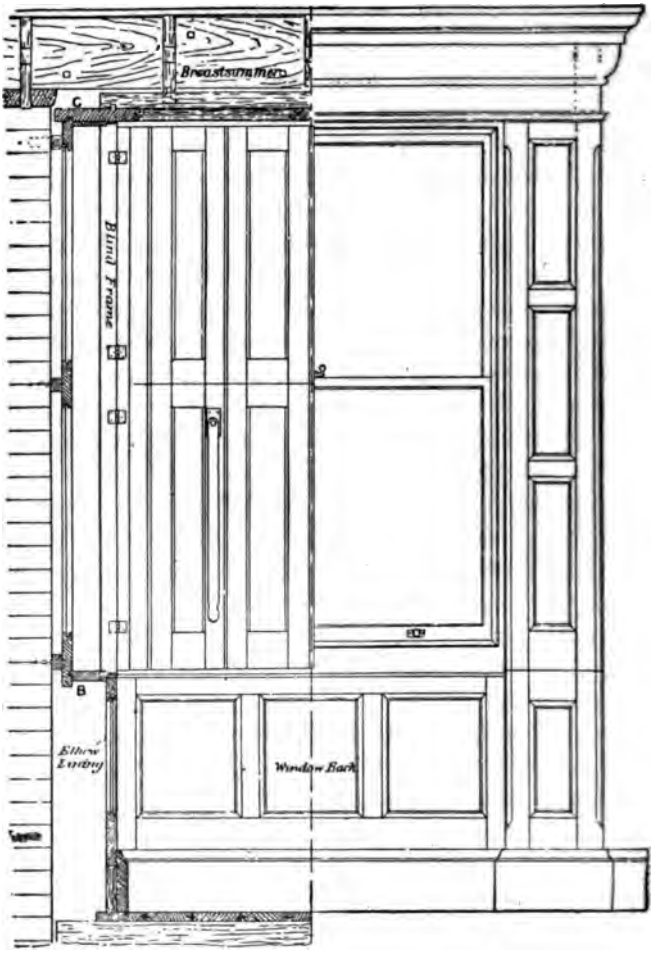


Fig. 55.

Fig. 55 is a sectional elevation of a Window Fitted with Boxing Shutters having a cover flap and spaces for a blind and a curtain. One-half of the elevation shows the shutters opened out and the front of the finishings removed, showing the construction of the boxings, &c. The plan, Fig. 56, is divided similarly, one-half showing the shutters folded back, with por-

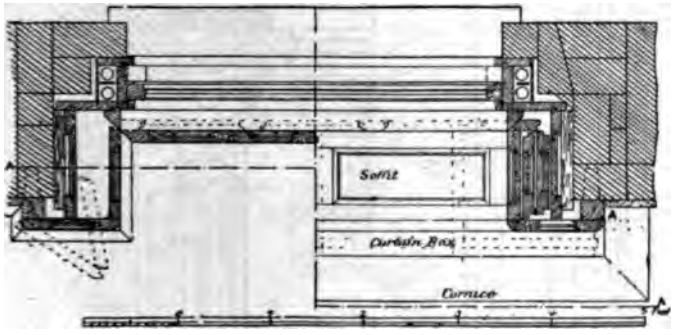


Fig. 56.

tions of soffit cornice, &c.; the other half gives the plan and sections of the lower parts, the dotted lines showing the window back.

Fig. 57 is a vertical section and Fig. 58 an enlarged section through the boxings. The framed pilaster covering the boxing is cut at the level of the window board, and hung to the stud A′, this being necessary for the cover to clear the shutters when open (see dotted lines on opposite half). The cover flap closes into rebates at the top and bottom, as shown in sec-

Fig. 57.

tion in Fig. 55. T
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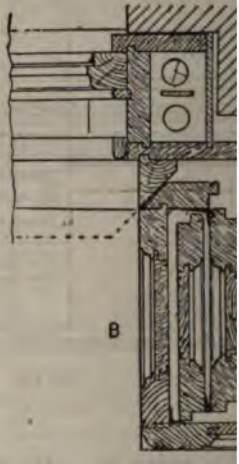

Fig. 5

into it, as shown i
Fig. 55. When t
an opening run f
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are called jamb
when they comm
the present instan

window board, they are termed elbow linings, the corresponding framing under the window being the window back.

Sliding Shutters are used instead of folding shutters in thin walls, and consist of thin panelled frames running between guides or rails fixed on the soffit and window board, which are made wider than usual for

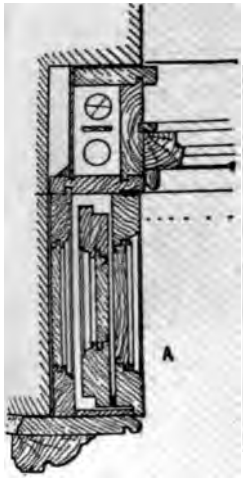


Fig. 59.

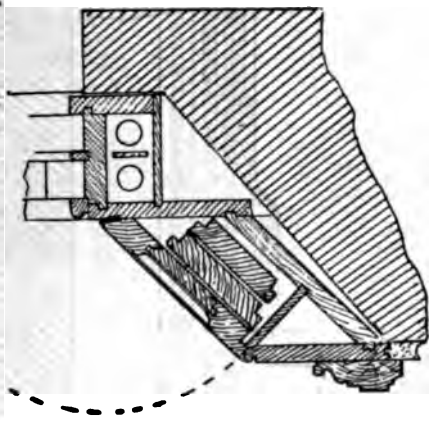


Fig. 60.

that purpose. When open, they lie upon the face of the wall adjacent to the opening. They are so seldom used that they do not call for illustration.

Balanced or Lifting Shutters are shown in section in Fig. 61, and plan in Fig. 62. They consist of thin panelled frames, the full width of and each half the height

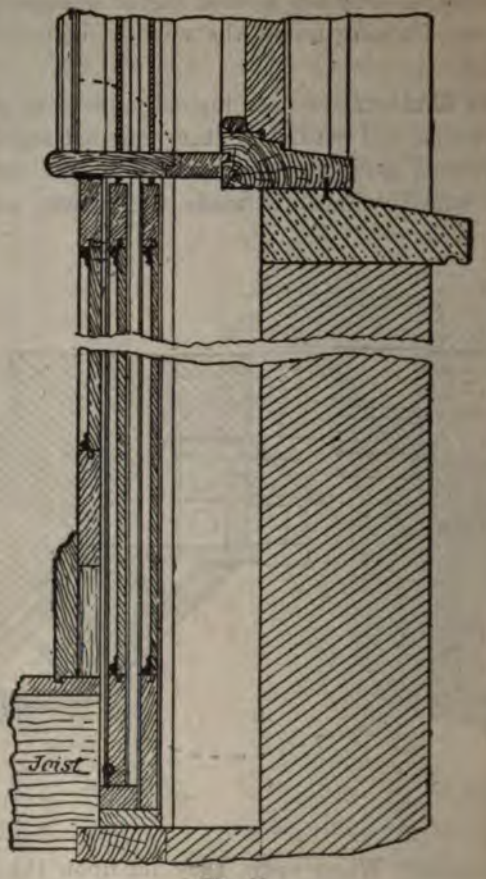


Fig. 61.

of the window, hung with weights in a cased fra
a similar manner to a pair of sashes. The fran
tends the whole height of the window, and is c
down behind the floor joists to the set off. The

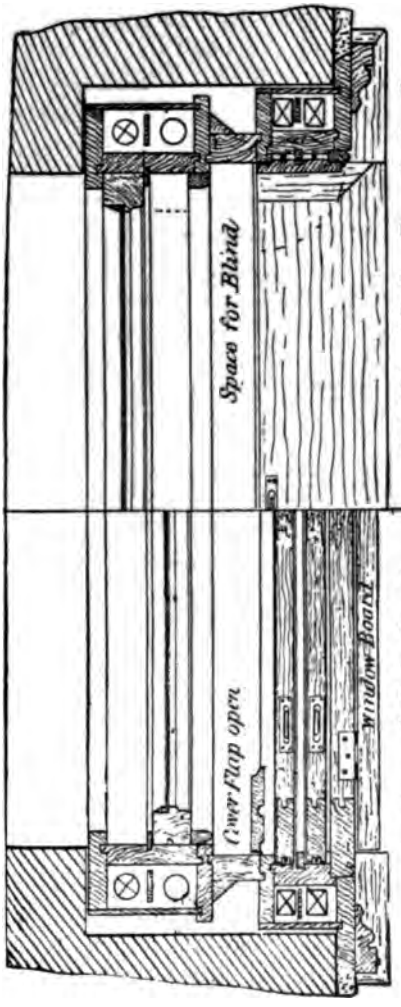

Space for Blind
Cover Flap open
Window Board
Half Plan with Window Board open
Half Plan Window Board closed

FIG. 62.

dow board is hinged to the front panelling or shutter back, so that when the former is lifted, the shutters can pass down behind the back out of sight. Cover flaps hung to the outer linings on each side close over the face of the pulley stiles and hide the cords. When it is desired to close the shutters, the cover flaps are opened out flat, as shown to the left of the plan. The

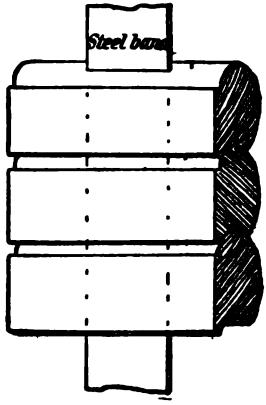


Fig. 63.

window board can then be lifted, and the shutters run up, a pair of flush rings being inserted in the top edge of each for that purpose. The window board is next shut down, the inside shutter brought down upon it, the outside one pushed tight up to the head, and the meeting rails, which overlap an inch, fastened with a thumb-screw. The bottom rail of the upper shutter is made an inch wider than the other, for the purpose of showing an equal margin when overlapped. Square lead weights have generally to be used for

these shutters in consequence of their comparative heaviness.

Rolling or Spring Shutters are made in iron, steel and painted or polished woods, and though somewhat monotonous in appearance, are, in consequence of their convenience in opening and closing, and in the case of the metal kinds, the additional security against fire and burglary, fast superseding all other kinds, both for internal and external use, especially in shops and public buildings. They consist, in the case of the wood varieties, of a series of laths of plano-convex, double convex, oval, or ogee section, fastened together by thin steel or copper bands passing through mortises in the centre of the thickness, as shown in Fig. 63, and secured at their upper ends to the spring container. These metal bands are supplemented by several waterproof bands of flax webbing glued to the back sides of the laths. The upper edge of each lath is rounded, and fits into a corresponding hollow in the lower edge of the one above it; this peculiar overlapping joint, whilst preventing the passage of light, etc., between the laths, readily yields when the shutter is coiled around the barrel. The spring barrel is usually made of tinned iron plate, and encases a stout spiral spring wound around an iron mandrel with squared ends to which a key is fitted for winding the spring up. The ends of the mandrel project from the case and are fixed in bracket plates at each end of the shutter—in the case of shop fronts, in a box or recess behind the fascia; one end of the spring is secured to the barrel, the other end to the mandrel; the shutter is secured to the barrel by the metal bands mentioned

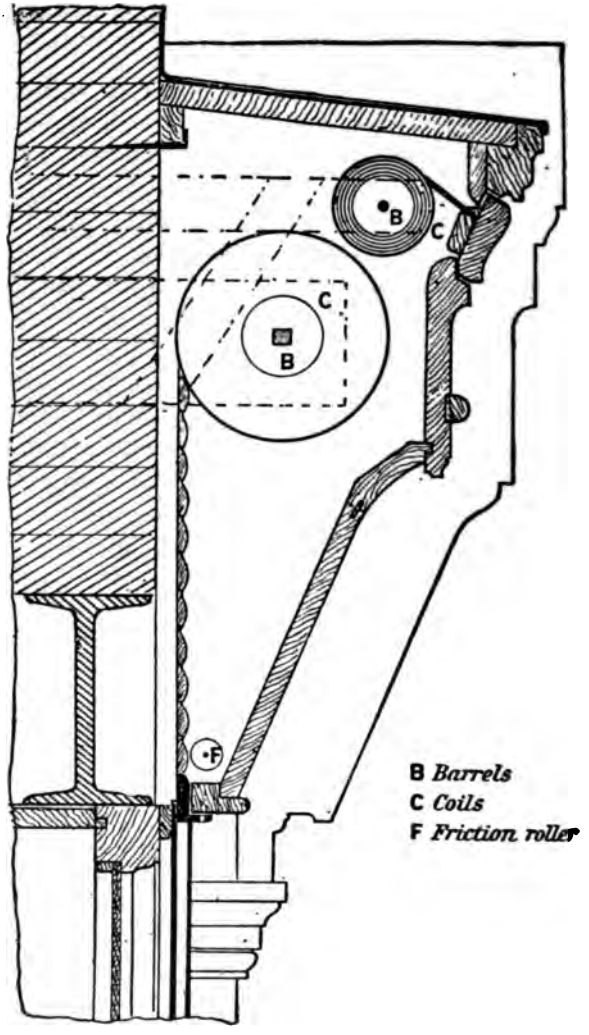


Fig. 64.

above, and the normal condition of things is that when the shutter is coiled up the spring is unwound. The pulling down of the shutter winds up the spring, and the tension is so arranged that it does not quite overcome the weight of the shutter and the friction when the shutter is down, so that the latter must be assisted up with a long arm. Great care should be taken in fixing these shutters to arrange the barrel perfectly level and parallel with the front, and to securely fix the brackets. These may be bolted to the girder or breast-summer, or screwed to the fixings plugged in the wall, as shown by dotted lines in Fig. 64. Where possible a wood groove should be formed on each side of the openings for the shutters to work in, but iron channels (Fig. 65) are frequently used. These are cemented into a chase in the wall or pilaster. Fig. 64 is a section through a shop fascia, showing shutter and blind barrels fixed to the face of the wall, where no provision has been made beneath the girder. Fig. 66 shows the adaption of one of these shutters to the inside of a window; the barrel is fixed in a seat formed beneath the window, the top of which is hinged, to gain access to the coil. The minimum space required for a coil, for a shutter about 6 ft. high is 10½ in. A friction roller F should be fixed close to the back rail to prevent chafing as the coil unwinds; the shutter is lifted by means of a flush ring in the L iron bar at the top, and this ring engages with a tilting hook in the soffit to keep the shutter up. The metal varieties of these shutters are wound up by the aid of balance weights or bevel wheel gearing.

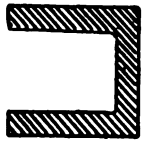


Fig. 65.

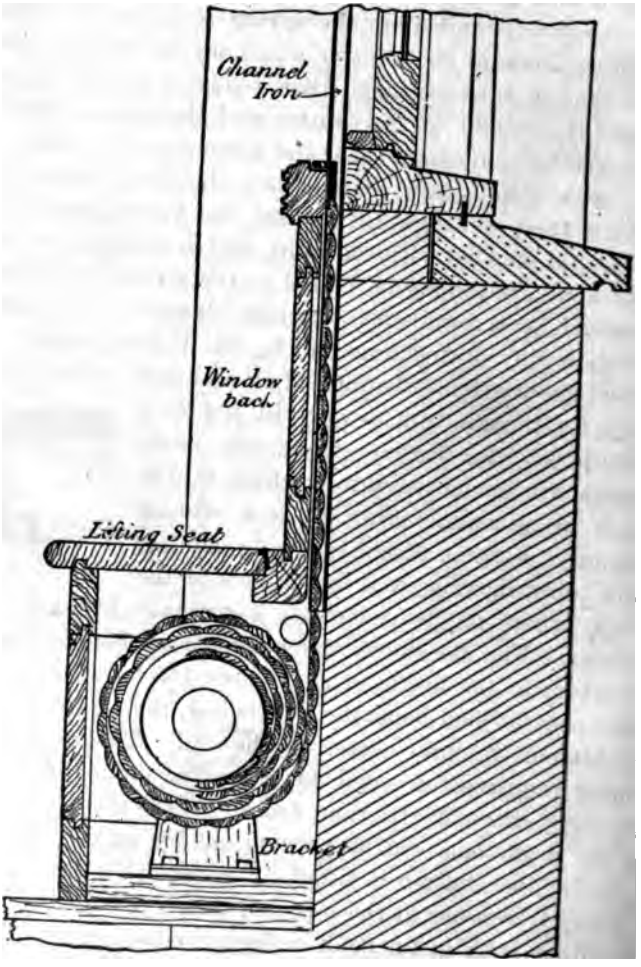


Fig. 66.

WINDOWS GENERALLY.

Size and Position. The size and position of window openings are influenced by the size of the room and the purposes for which the building is used. For the sake of ventilation, and also to secure good lighting, the windows should be placed at as great a height as the construction of the room will allow. In dwelling-houses the height of the sill is usually about above the inside floor level.

Construction. The framework holding the glass in the window may be fixed or movable. It must be so prepared that the glass can be replaced when necessary. In warehouses, workshops and similar buildings, the frames holding the glass are often made as **Fast Sheets** (Fig. 66½). As, however, this arrangement affords no means of ventilation, it is usual to have the glass fixed in lighter frames called **Lights**. When the sashes are hung to solid rebated frames, and open as doors do, the windows are called **Casement Windows**. If they slide vertically and are balanced by weights, or by each other, the window is a **Sash and Frame Window**. Other methods of arranging windows are by hinged, pivoted or made to slide past each other, and are described in detail later.

Sashes. The terms used for the various parts of sashes and fast sheets are somewhat similar to those employed in describing doors. Thus, the **Styles** are the outer uprights, and the **Rails** are the main horizontal cross-pieces: top rails, meeting rails, and bottom rails being distinguished. Any intermediate rails, whether vertical or horizontal, are named **Bars**.

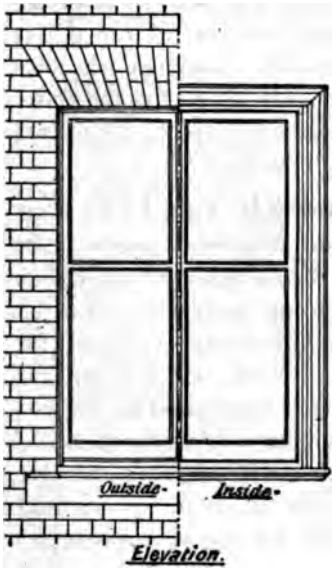


Fig. 73.

Fig. 74.

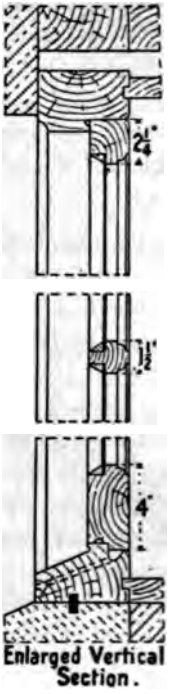


Fig. 75.

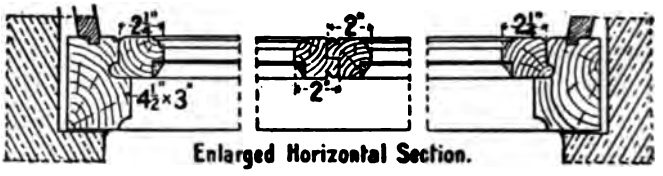


Fig. 76.

and sill. The head and sill "run through" and are mortised near the ends to receive tenons formed on the ends of the jambs. The upper surface of the sill is weathered to throw off rain water. Casement windows which reach to the floor are usually called **French Casements**. Their sashes require an extra depth of bottom rail.

Casement Sashes Opening Inwards. Figs. 73, 74 show the elevation and vertical and horizontal sections, of a window opening in a 14" brick wall fitted with a casement window having folding sashes to open inwards. In this class of window the frame is rebated for the sashes on the inner side. Each sash has, on the outer edge of the outer style, a semi-circular tongue, which fits into a corresponding groove in the jamb of the frame. This tongue renders the vertical joint between the sash and frame more likely to be weather proof; it is to provide for the tongue that the extra width of style already referred to is necessary. The tongue, however, is often omitted, as in Fig. 77. It will be seen readily that, if the sash were in one width, it would be impossible to have a tongue on more than one edge of it. With casement sashes opening inwards the greatest difficulty is found, however, in making a water-tight joint between the bottom rail of the sash and the sill of the frame. Figs. 77 and 78 show two methods by which this may be accomplished. An essential feature of all these sashes is a small groove or **Throating** on the under edge of the bottom rail; this prevents the water from getting through. The groove in the rebate of the sill (Fig. 78) is provided to collect any water that may drive through the joint. This

Casement Sashes Opening Outwards. These are more easily made weatherproof than inward-opening sashes. The chief objections to their adoption are that they are not easily accessible for cleaning the outside, especially in upper rooms and that they are also liable, when left open, to be damaged by high winds and to let in the rain during a storm. Fig. 81 is a sketch of one corner of such a window. It will be noticed that these

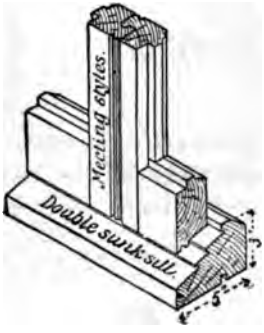


Fig. 80.

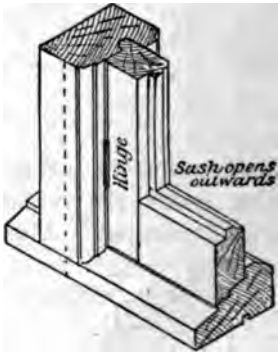


Fig. 81.

frames, like door frames, have the exposes arrises moulded in various ways, and that the sashes may either be hung flush with one face of the frame (as in Figs. 76 and 77), or fit in the thickness of the frame (Figs. 78 and 81). The sill shows to be **Double Sunk,** i. e., to have the upper surface—upon which the bottom rail of the sash fits—rebated with two slopes (weatherings).

Sash and Frame Window. In this class of window, which is by far the most common, because it is easily made weatherproof, there are **Two Sashes**, which slide past each other in vertical grooves, and are usually balanced by iron or leaden weights. As will be seen from Fig. 82 the frames form cases or boxes in which the weights are suspended. They are hence called

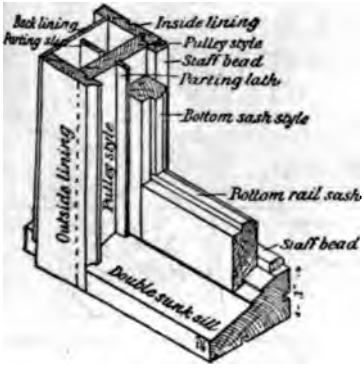


Fig. 82.

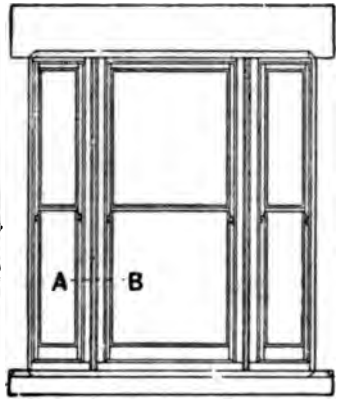


Fig. 82½.

Cased Frames. **Pulley Styles** (Fig. 86) take the place of the solid rebated jambs of casement windows. The pulley styles, **Outside** and **Inside Linings**, and **Back Lining** (Fig. 82) together form a box which is subdivided by a vertical **Parting Slip** suspended as shown in Fig. 82. In superior window frames of this kind, the pulley styles and linings are tongued and grooved together as shown in Fig. 83. In commoner work the tongues and grooves are often omitted. The frame

must be so constructed that the sashes can be removed easily for the purpose of replacing broken sash-lines. To enable this to be done, the edge of the inside lining is either made flush with the face of the pulley style (Fig. 83), or it is rebated slightly as shown in Fig. 83. The edge of the outside lining projects for a distance of about three-quarters of an inch beyond the face of the pulley style, to form a rebate against which the outer (upper) sash slides. The outer sash is kept in

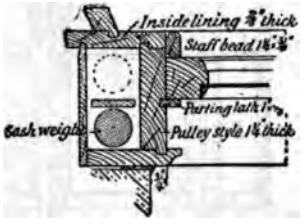


Fig. 83.

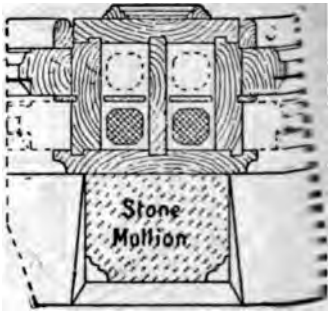


Fig. 83½.

position by the **Parting Lath** (Fig. 82) which fits into a groove in the pulley style. The groove for the inner (lower) sash is formed by the parting lath and a **Staff Bead** or **Stop Bead** which is secured by screws. The staff bead on the sill is often made from two to three inches deep to allow the lower sash to be raised sufficiently for ventilation at the meeting rails without causing a draught at the bottom (Fig. 83).

A vertical section through the head of the frame is similar to a horizontal section across the pulley style,

except that the back lining and parting slip are of course absent.

The sill of the frame is solid and weathered, and should always be of hardwood, preferably oak or teak. The sill has a width equal to the full thickness of the frame. When the weathering has two steppings, it is known as a **Double Sunk Sill.** An alternative to the plan of having the width of the sill of the full thickness of the frame, is to arrange it so that the outside edge is flush with the outside face of the bottom sash, as shown in Fig. 89. With a sill arranged in this manner, and double sunk, there is less danger of water driving

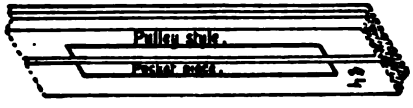


Fig. 84.

through the joint between the sash and the sill than with a sill the full thickness of the frame. In order to render watertight the joint between the wooden and stone sills of window frames, a metal tongue is often fixed into corresponding grooves cut into the under side of the wooden sill and the upper surface of the stone sill. A rebated joint between the two sills serves the same purpose as the metal tongue.

Fig. 84 shows the methods of fixing the pulley style into the head and sill respectively, when the width of the sill is equal to the full thickness of the frame. The **Pulleys** on which the sash lines run—sash or axle pulleys are fixed in mortises near the upper ends of the

pulley styles. It is also necessary to have a removable piece in the lower part of each pulley style, to allow of access to the weights. This piece is named the **Pocket Piece.** It may be cut as shown in Fig. 85; its position is then behind the lower sash, and it is hidden

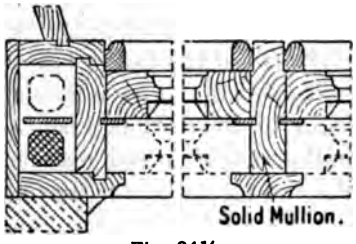


Fig. 84½.

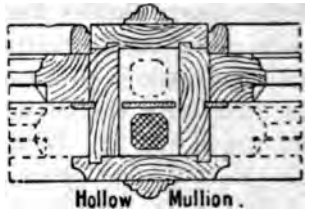


Fig. 85½.

from view when the window is closed. Or, the pocket piece may be in the middle of the pulley style as shown in Fig. 84; the vertical joints between the pocket piece and the pulley style are then V shaped to prevent damage to the paint in case of removal.

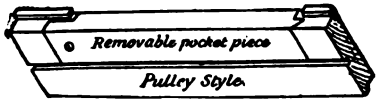
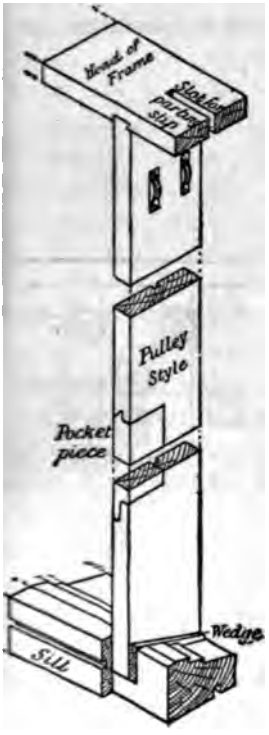


Fig. 85.

Sashes. The only difference between the joints of sliding sashes and those of the casement sashes already described is in the construction of the meeting rails. Each of the meeting rails is made thicker than the sash to the extent of the thickness of the parting lath; otherwise there would be a space between them equal to the

thickness of the parting lath. The joint between them may be rebated or splayed. The angle joints between the ends of the sash styles and the meeting rails are



Joints at ends of Pulley Style.

Fig. 86.

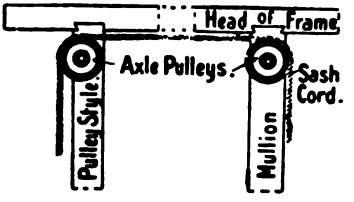


Fig. 86½.

often dovetailed as shown in Fig. 86. They are, however, stronger if the styles are made a little longer, the projecting part being moulded, and mortise and

tenon joints used as shown in Figs. 86 and 87. The projecting ends of the styles are called **Joggles**; they assist in enabling the sashes, especially in wide windows, to slide more freely. When as is usually the case, both sashes slide and are balanced by weights, the

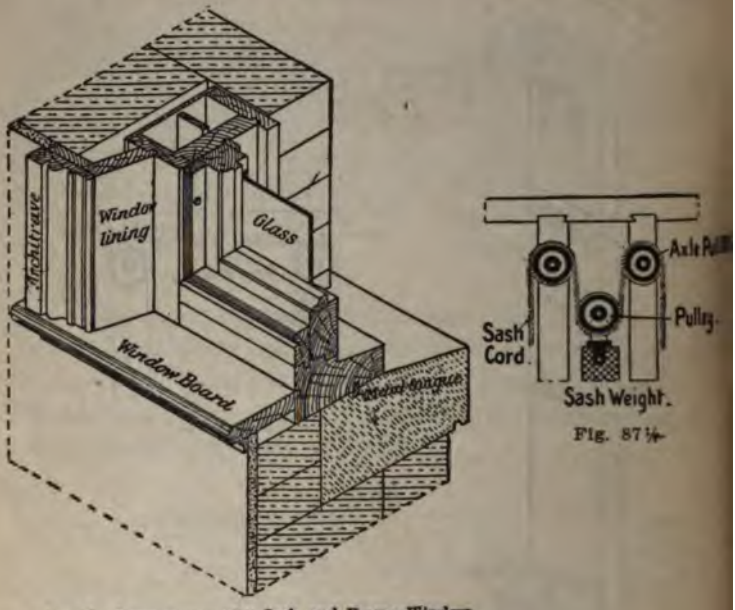


Fig. 87½

Sketch of one corner of a Sash and Frame Window.

Fig. 87.

window is known as a **Double-Hung** sash and frame window. If one sash only slides, and the other is fixed in the frame, the window is **Single-Hung**. Figs. 78 to 80 show the details of a sash and frame window fixed in a one-and-a-half-brick-thick wall and having a stone head and sill.

For the sake of appearance, or when it is required to have wider windows than can be arranged with one pair of sashes, two or three pairs of sashes are often constructed side by side in the same frame. When three pairs of sashes are used, it is usual to have the middle pair wider than the others; such a combination (Fig. 73) is named a **Venetian Window.** The vertical divisions between adjacent pairs of sashes are called **Mullions.** These mullions may be constructed in several different ways. If the middle pair of sashes only is required to slide, the mullions may be solid from 1¼" to 2" thick, and the sash-cord conducted by means of additional pulleys to the boxes, which are at the outer edges of the frame. Figs. 84 and 86 show this arrangement. If it is desirable to have all the sashes to slide, the mullions must be hollow to provide room for the weights. Figs. 85 and 87 show details of a mullion with provision made for one weight to balance the two sashes adjacent to it. With this arrangement the sash-cord passes round a pulley fixed into the upper end of the weight. If stone mullions are used in the window opening, separate boxings may be made so that each pair of sashes is hung independently as shown in Fig. 83, and the window becomes, as it were, two or three—as the case may be—separate window frames, with the sill and head each in one length for the sake of strength.

The Hanging of Vertical Sliding Sashes. As shown in illustrations already given, the sashes of sash and frame windows are balanced by cast-iron or leaden weights. The best cord is employed for hanging sashes of ordinary size, while for very heavy sashes the sash

lines are often of steel or copper. The staff bead and parting bead having been removed, the cords are passed over the axle pulleys (which are best of brass to prevent corrosion) and are tied to the upper ends of the weights. The weights are passed through the pocket holes and suspended in the boxes. The pocket pieces having been replaced, the upper sash, which slides in the outer groove, is hung first, the free ends of the cords being either nailed into grooves in the outer edges of the sash or secured by knotting the ends after passing them through holes bored into the styles of the sash. The upper sash having been hung, the parting laths are fixed into the grooves in the pulley styles, and the lower (inner) sash is hung in a similar manner, after which the staff beads are screwed in position. Care should be taken to have the cords of the right lengths; if the cords for the upper sash are too long the weights will touch the bottom of the frame, and cease to balance the weight of the sash before the latter is closed. If the cords for the lower sash are too short, the weights will come in contact with the axle pulleys, and thus prevent it from closing. Several different devices for hanging sashes—the objects of which are either to render unnecessary the use of weights or to facilitate the cleaning of the outside of the window—have been patented, and are in more or less general use. A detailed description of these is, however, beyond the scope of this book.

Bay Windows. A bay window is one that projects beyond the face of the wall. The side lights may be either splayed or at right angles to the front. The window openings may be formed by having stone or

brick mullions or piers at the angles, against which the window frames are fixed, or the wooden framework of the window may be complete in itself. When the latter is the case, it is usual to have stone or brick

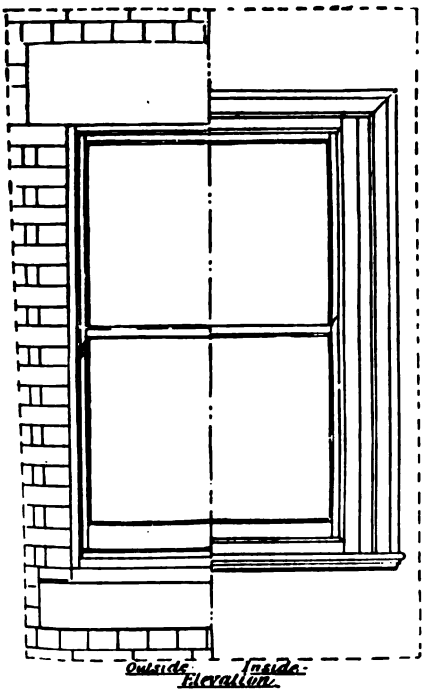


Fig. 88.

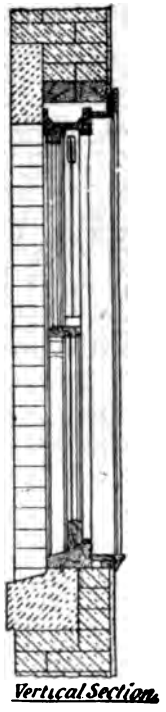


Fig. 89.

work to the sill level as shown in Fig. 88. Bay windows naturally lend themselves to decorative treatment. With the addition of masonry or brickwork they often assume a massive and bold appearance. When

usually by a wooden cornice, and the wooden roof is covered with lead, slates or tiles. The window frames may be arranged as fixed lights, sash and frame, or

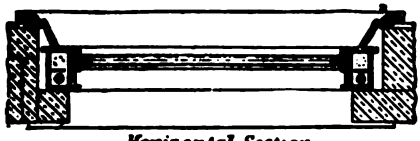
Front Elevation.
Fig. 88½.

Fig. 89½.

casements. The most usual arrangement is to have the lower lights fixed, and the upper ones as sashes hinged to open for ventilating purposes. Figs. 88 to 90

show the details of a bay window with splayed side lights, the upper side lights being hinged on the transom to open inwards.

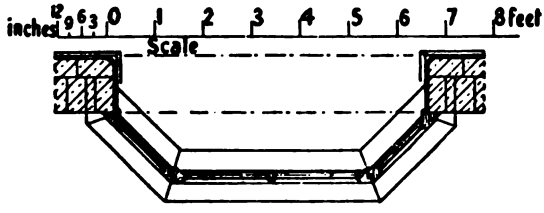
Windows With Curved Heads. When a window opening is surmounted by an arch, the top of the window frame requires to be off the same curvature as the under side (soffit) of the arch. In the case of fixed



Horizontal Section.

Fig. 90.

sashes, or of solid frames with casement sashes, the head of the frame is "cut out of the solid." A head which, owing to the size of the curve, cannot easily be obtained in one piece, is built up of segments, the

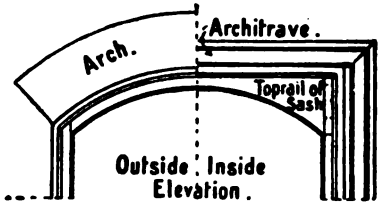


Horizontal Section.

Fig. 90½.

joints being radial to the curve, and secured by hardwood keys. As an alternative method, the head may be built up of two thicknesses—with overlapping joints—and secured together by screws,

A sash and frame window in such an opening may have only the outside lining cut to the curve of the arch, the inner side of the frame being left square. The upper sash will then require a top rail with a straight upper edge and a curved lower edge, as shown in Fig. 91.



Elevation of upper part of a Window having Curved Head.

Fig. 91.

When the head of the frame has to be curved, it may

(1) be built up of two thicknesses with overlapping joints, and secured by screws; it may

(2) be formed of three thicknesses of thin material bent upon a block of the correct radius, and well glued and screwed together; or

(3) the head may be of the same thickness as the pulley styles, with trenches cut out of the back (upper) side, leaving only a veneer on the face-side under the trenches. Wooden keys are glued and driven into the trenches after the head has been bent upon a block to the required shape.

A strip of stout canvas glued over the upper side will strengthen the whole materially. The outside and

e linings are in such a case cut to the required
ture, and when nailed in position hold the head
ipe. The end joints of the linings may have hard-
cross-tongues.

p Windows. The main object in view in the con-
ion of shop windows is to admit the maximum of
and to give opportunity for an effective display
goods. The glass is in large sheets, and there-
especially thick to secure the necessary strength.
windows are usually arranged as fast sheets, with
ion for ventilation at the top. The glass is held
ition by wooden fillets, and is fixed from the in-
de. The chief constructional variations are found
pilasters, cornice, provision for sign-board, sun-
and the arrangement of the side windows. Figs.
95 show the details of a typical example.

Fixing of Window Frames. Window frames
be built into the wall—which has usually a re-
l opening to receive them—as the brickwork pro-
or they may be fixed later. In the former case,
ids of the sill and head project and form **Horns,**
are built into the brickwork and help to secure
ame. Wooden bricks or slips may also be built
he wall, the frames being nailed to them.

he latter case, the frames are secured by wooden
es, which are driven tightly between the frame
ie wall. These wedges should be inserted only at
ids of the head and sill and directly above the
; otherwise the frame might be so strained as to
re with the sliding of the sashes. Window
; as well as door frames should be bedded
t a layer of hair-mortar placed in the recess.

Fig. 92.

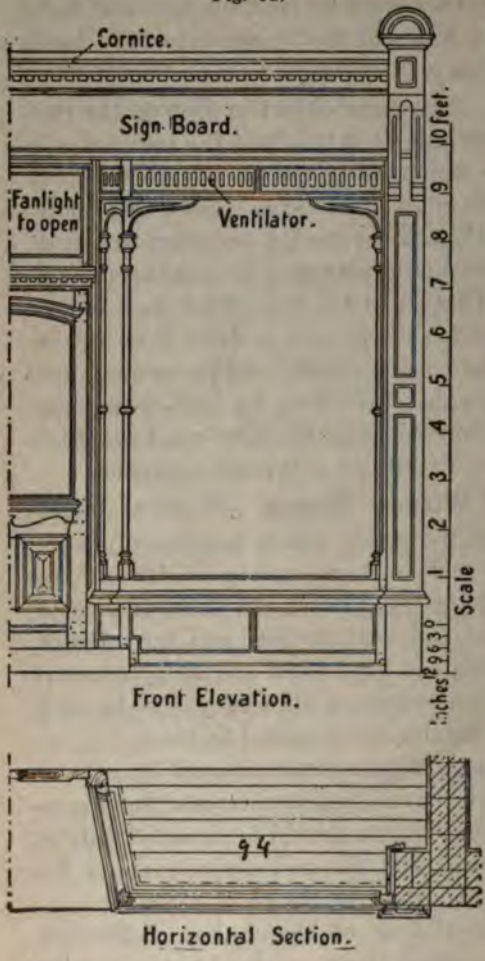
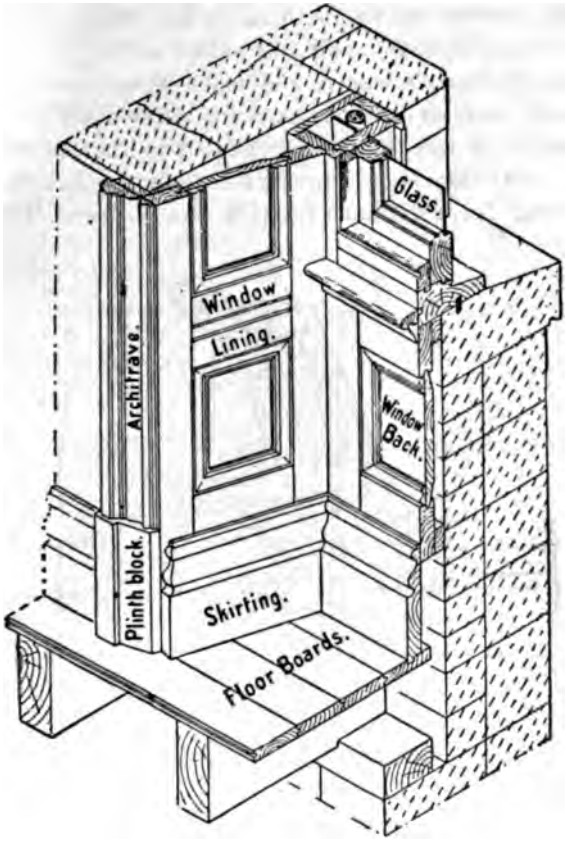

Cornice.
Sign Board.
Fanlight to open
Ventilator.
10 feet.
9
8
7
6
5
4
3
2
1
Scale
Inches 9 6 3 0
Front Elevation.
94
Horizontal Section.
Slide Hit &
Ventilat
Condensat
Gutter.
93
Vertical S

Fig. 94.



Sketch of part of a Sash and Frame Window, showing Panelled and Moulded Jamb-lining, etc.

Fig. 95.

Linings. When window frames are not of sufficient ickness to come flush with the inner face of the wall, e plaster may be returned round the brickwork and

finished against the frame, or a narrow fillet of wo
may be scribed to the wall and nailed to the frame.
dwelling-houses, however, the more usual way is
fix linings similar to those used for outer door fram
The width of the linings depends upon the thickn
of the wall; they should project beyond the inner f
of the wall for a distance equal to the thickness of t

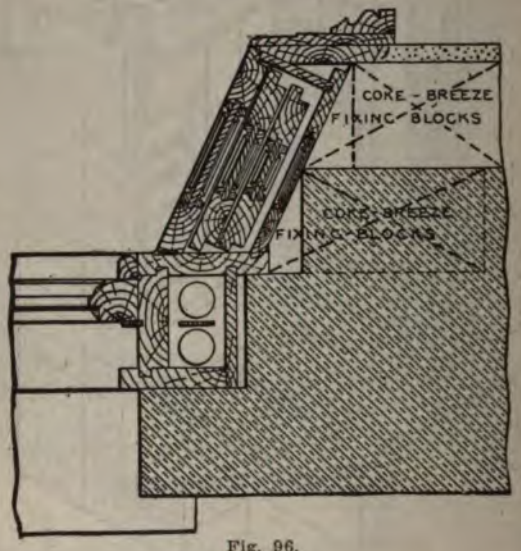


Fig. 96.

plaster, and are usually splayed so that they will
interfere with the admission of light. The inside
window and door openings usually are finished simil
ly; thus, the **Architrave,** or **Band Moulding,** which
secured to the edge of the linings and to rough wood
Grounds is fixed along the sides and top in both ca

The bottom of the window opening is finished with a **Window Board** which is tongued into the sill of the frame. The board is about 1¼ inches thick, and is made wide enough to project beyond the surface of the plaster for a distance of about 18 inches. The projecting edge is nosed (rounded) or moulded. It is longer than the opening, to allow the lower ends of the architrave to rest upon it.

When the walls are thick, the linings are often framed and panelled. Such linings may terminate on a window board at the sill level, or the inner side of the wall may be recessed below the sill level and the linings carried to the floor as shown in Fig. 96.

Window Shutters. Although not used to the same extent as formerly, wooden window shutters are fitted occasionally to close up the window opening. Window shutters, which are arranged generally on the inner side of the window, may be hinged as box shutters, or may be vertically sliding shutters.

Box Shutters consist of a number of leaves or narrow frames which are rebated and hinged together, an equal number being on each side of the window opening, the outer ones on each side being hung to the window frame. When closed they together fill the width of the window-space, and when open they fold behind each other so that the front one forms the jamb lining of the window frame. If the walls are thick, the shutters can be arranged to fold in the thickness of the wall; if the wall is a thin one it is necessary to construct projecting boxes into which the shutters fold. The nature of the framing of the shutters depends upon the surrounding work; it is usual to have the outer sur-

face framed and moulded, and the inside finished bead-flush. The arrangement of box shutters requires that the shutters on the same side shall vary in width so that they will fold into the boxes on each side of the window, the outermost shutter (which is the widest) then acting as the window lining. Fig. 96 shows a horizontal section through one side of a window, showing hinged shutters folding so that a splayed lining is obtained. Fig. 97 shows hinged shutters consisting of one narrow and one wide shutter on each side of the

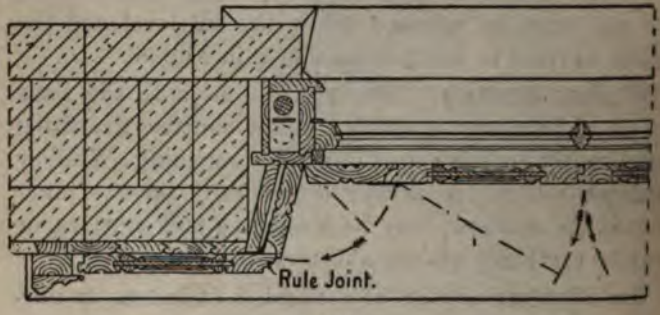


Fig. 97.

opening. This arrangement is suitable for a thin wall, where it is undesirable to have boxes for the shutters projecting beyond the face of the wall. For hanging window shutters it is usual to use back-flap hinges; the joint at the corner of the shutters in Fig. 97 is named a rule joint.

Sliding Shutters, working in vertical grooves and balanced by weights, are sometimes used. They require that the wall under the window sill shall be recessed; the floor also often needs trimming to allow

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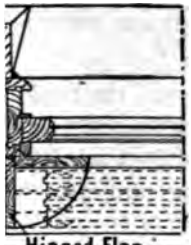

Hinged Flap.
ights for Shutters.

g. 99.

. Figs. 98 and
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Skylights.

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open are fit-
the upper
a **Curb** or
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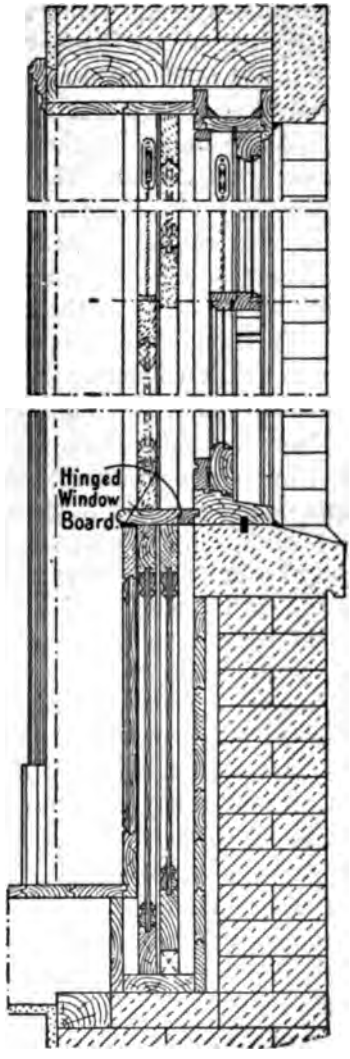


Fig. 98.

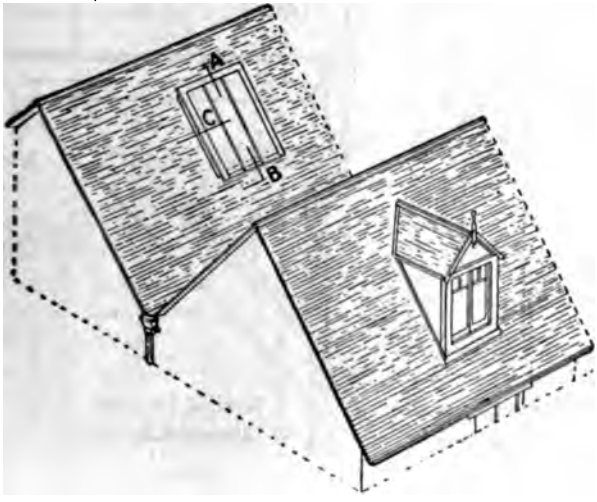
mon rafters being "trimmed" to the required size to receive the curb. The curb is made from material 1¼ to 2 inches thick, and of width such that its upper edge stands from 4 to 6 inches above the plane of the roof. The **Angle Joints** of the curb may be dovetailed or tongued and nailed. The **Sash Frame** rests upon the upper edge of the curb; it is from 2 to 2½ inches thick, and consists of stiles and top rail of the same thickness, and a bottom rail which is thinner than the stiles by the depth of the rebate. Bars are inserted in the direction of the slope of the roof, and the butt hinges used for hanging the sash are invariably fixed as the under side of the top rail.

The joints between the curb and the roofing slates or tiles are made weatherproof with sheet lead. At the upper end—the back of the curb—a small **Lead Gutter** is formed, with the lead going underneath the slates and overlapping the upper edge of the curb. The sides of the curb may be flashed with soakers—short lengths of sheet lead which are worked in between the slates—or the joint may be made with one strip of lead forming a small gutter down the side of the curb. In either case the lead overlaps the upper edge of the curb. At the lower end of the curb, the lead overlaps the slates. To prevent water from rising between the glass and the upper side of the bottom rail, sinkings are cut into the rail. (See Fig. 100).

Dormer Windows. Instead of having the light in or parallel to the plane of the roof, it affords a more artistic treatment of the roof, and often gives a better result in lighting, if the window is fixed vertically. The general arrangement of the framing, as well as of the

sashes, depends upon the kind of roof, the width of the window required, and the general style of architecture of the building.

The construction of a dormer window necessitates trimming of the rafters, and the arrangement of projecting framework, the front of which consists of **Cor-**



Sketch of part of the Roof of a Building, showing a Hinged Skylight and a Dormer Window.

Fig. 100.

ner Posts and **Crossrails**—rebated to receive hinged sashes—which are connected to the main roof by other crossrails and by **Braces**. This framework is surmounted by a **Roof** which may be either ridged, or curved outline, or flat. By arranging a ridged roof to over-

hang, and adding suitable **Barge Boards** and **Finial** (Fig. 101) a dormer window may be made to improve the general appearance of the roof of a building. The sides of the dormer may be either boarded and covered with the same kind of material as the roof, or they may be framed for sidelights.

Fig. 101.

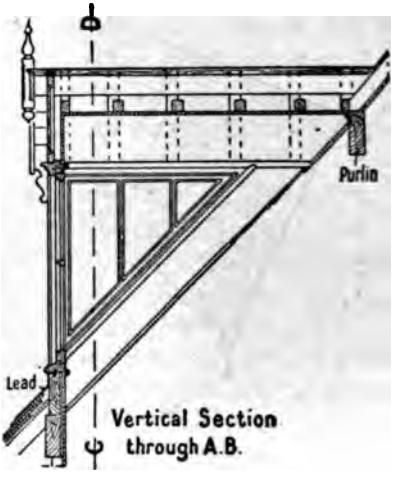


Fig. 102.

As dormer windows are generally in exposed positions, and the sashes are arranged as casements to open, their efficiency depends largely upon the perfection of the joints between the sashes and the frame. It ought to be mentioned however, that with sashes hung folding, semicircular tongues on their hanging stiles are by far the best. Figs. 101 and 102 give the details of

a dormer window, with sidelights, fixed in a roof of ordinary pitch. The sashes, which are hung folding, open inwards. The roof may be boarded and covered with lead, or it may be covered with slates or tiles. The joints between the roofing slates of the main roof, and the roof and sides of the dormer, are made weatherproof with sheet lead flashings. Figs. 103 and 104 show a dormer window fixed in a Mansard roof; in this example there are no side lights.

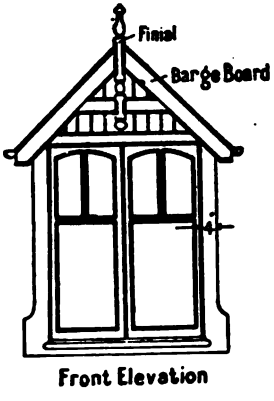


Fig. 103.

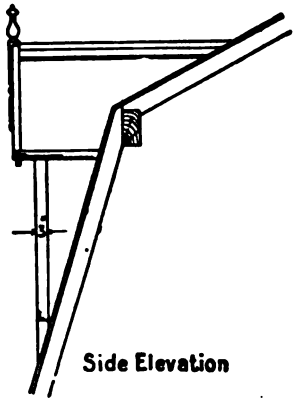


Fig. 104.

Large Skylights and Lantern Lights. For lighting the well of a large staircase, or a room which, for some reason, cannot be lighted with side windows, specially large skylights are often necessary. These are of a more elaborate construction than the skylights already described; they vary considerably in size, shape and design; the plan may be rectangular, polygonal, cir-

cular, or elliptical, and the outline may be pyramidal, conical, or spherical. The framework may be of either wood or iron. To support such a skylight, a strong wooden curb is framed into the roof, and projects from 6 to 9 inches above the roof surface. The joints between the curb and the roof are made watertight with sheet lead. The framework of the skylight may consist of rebated quartering; with separate lights which fit into the rebates of the framing; or the sashes them-

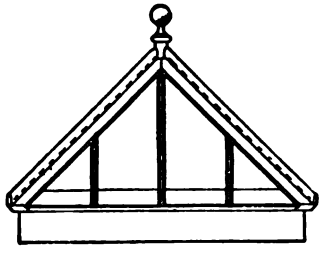


Fig. 105.

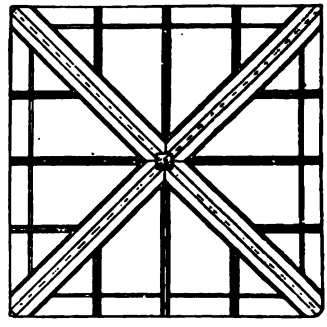


Fig. 106.

selves may be constructed with strong angle stiles, which are mitred together, and provided with either a hardwood tongue inserted in the joint, or with a wooden roll on top to keep out the water.

With skylights of this description, channels for condensed water should always be provided. These are placed at the upper inner edge of the curb, the remainder of the inside face of the curb being covered by either panelled framing or match boarding.

Figs. 105 and 106 give details of a skylight having the form of a square pyramid. In this example the four triangular lights are mitred at the angles, and have wooden rolls over the joints. Figs. 107 and 108 show elevation and part plan of a skylight with a curved roof surface.

A Lantern Light differs from the skylights just described in having, in addition, vertical **Sidelights**. The sidelights consist of sashes, which, by being hinged or

Fig. 107.

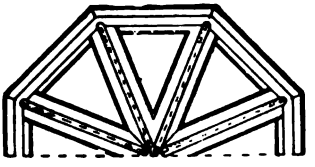


Fig. 108.

pivoted, are often available for ventilation. As they are in exposed positions, the greatest care is required in order to obtain watertight joints. When the sidelights are hinged on the bottom rail, they open inwards; when on the top rail they open outwards. When they are hung on pivots, the pivots are fixed slightly above the middle of the sash. Figs. 109 and 112 show details of a rectangular opening surmounted by a lantern light which is hipped at both ends, and has sidelights arranged to open inwards.

The construction of skylights and lantern light fords good examples of the application of geon to practical work as described in previous pages. V

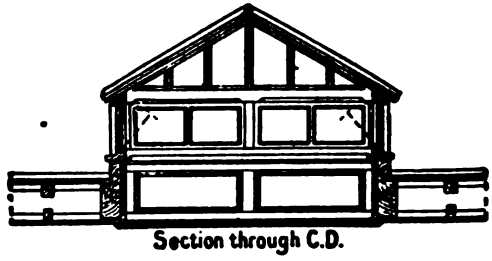


Fig. 109.

the roof-lights are pyramidal as shown in Figs. 106 110, and a separate frame is constructed as show

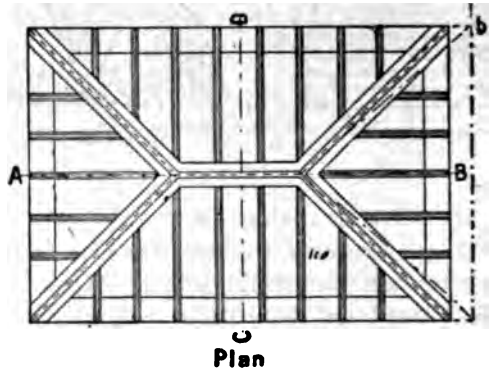


Fig. 110.

Fig. 110, the methods of obtaining the lengths bevels of the hip rafters are similar to those desc for getting hip rafters. When the roof-lights a

against one another, the sizes of the lights and the bevels of the angle stiles which mitre together are obtained as shown at X in Fig. 112. With lights of

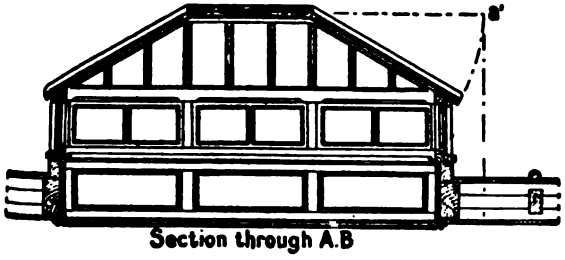


Fig. 111.

curved outline, the shapes of the hip rafters or angle-stiles, as well as the developed surfaces, are obtained as explained before.

Lay-Lights. At the ceiling level of roof-lights used for staircase wells, or in similar positions, it is often

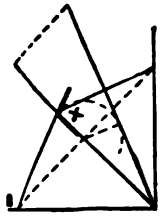


Fig. 112.

Fig. 113.

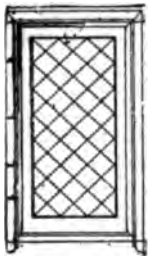


Fig. 114.

considered advisable, for the sake of appearance, to have a horizontal second light called a lay-light. This consists of a sash—or if the space is large, a number of sashes—fixed into frames in the ceiling. The chief

feature of lay-lights is in the attempt at decoration by arranging the bars in some ornamental design (Figs. 113 and 114). The lay-lights are often glazed with ornamental glass, which, although it improves the appearance, diminishes the amount of light transmitted.

Greenhouses and Conservatories. In this type of building which is largely constructed of wood and glass, the framework is usually of moulded and rebated quartering, with side sashes fixed in the rebates. As in the case of skylights, the roof-lights, which in this case reach from the ridge to the eaves, have no crossbars, since these would impede the flow of water running down the slope of the roof. Care should be taken to have the bars strong enough to carry the glass without sagging; and it is well to remember that when a roof is of flat pitch a heavy snowstorm will throw a large additional weight upon it, while with a steep roof the wind has much power. The distance apart of the bars which carry the glass ranges from 12 to 18 inches, and the lengths of the sheets of glass should be as great as possible, so as to diminish the number of cross-joints, since these allow of accumulations of dirt which cannot be removed easily. These roof-lights are constructed in exactly the same manner as skylights; they are, however, often much larger, and require to be thicker, unless purlins are placed to support them. When, as is often the case, part of the roof-light is made to open, this part—often a narrow strip at the highest part of the roof (Fig. 115)—is made as a separate light, which overlaps the upper edge of the fixed lower light. Additional ventilation is secured by arranging the side sashes to open.

The above description is intended merely to outline the broad principles of the construction of conservatories, but it should be remembered that the details, while conforming to casement and roof-light construction generally, lend themselves to considerable variation in design and arrangement.

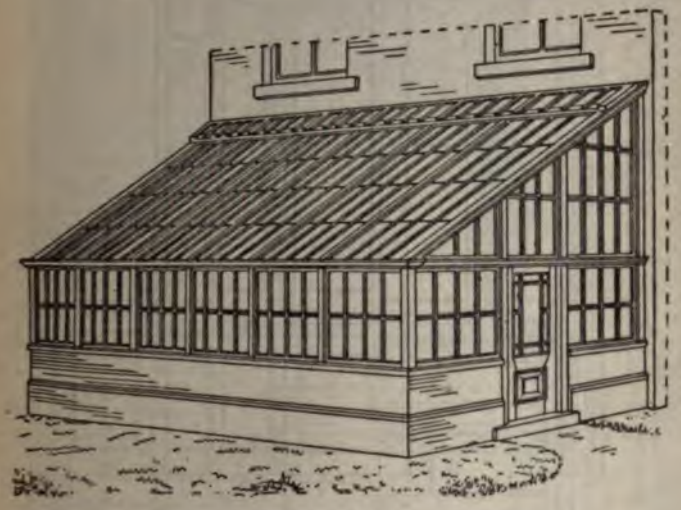


Fig. 115.

A Bay Window with solid frame and casement lights is shown in Fig. 116 to 118. Two methods of fitting such a window, with folding shutters, are given in this plan. In the half plan at C, the shutters fold into a boxing projecting into the room, and at D they fold back upon the face of the wall, which is splayed to receive them. The sills of the frame are mitred at

the angles, the joint cross tongued and fixed with a handrail bolt, which should be painted with red lead before insertion. The joints in the head are halved together, the mullions stub tenoned and fixed with

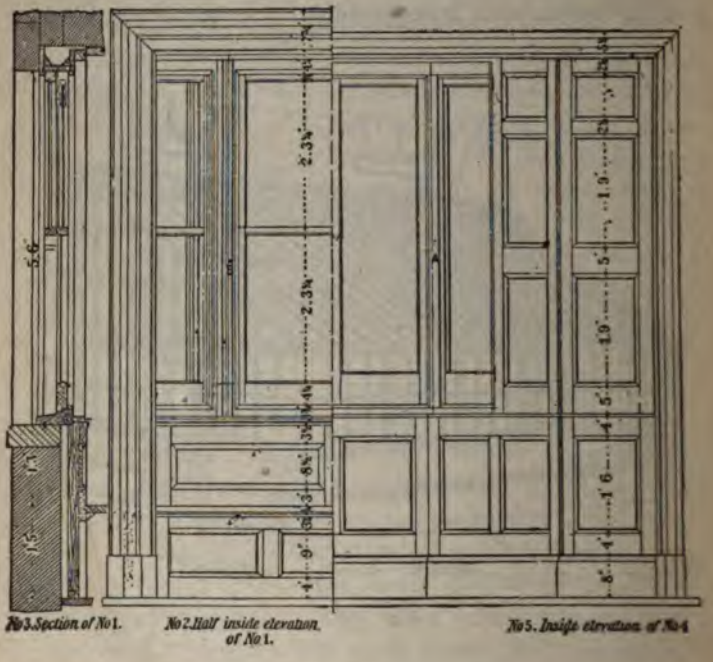


Fig. 116.

coach screws. The jambs are tenoned and wedged into the head and sill. The transom tenoned into the jambs and mullions, and secured with bolts. The mullions may be worked in one piece as shown at D, or built up as at C, and tongued and screwed together.

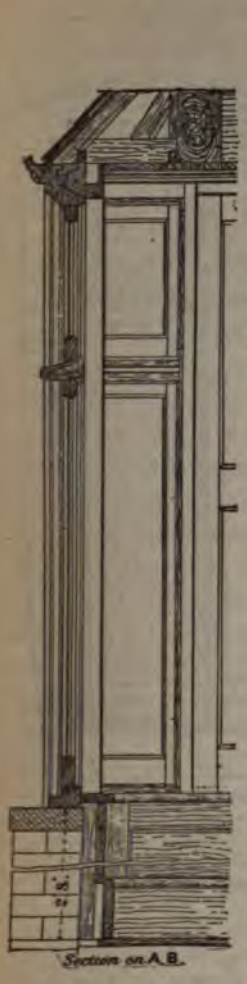


Fig. 117.

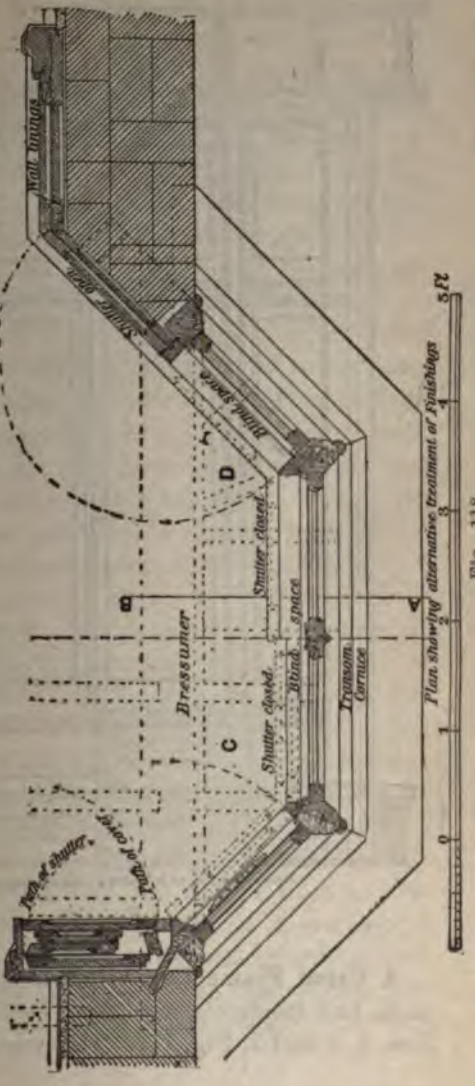


Fig. 118.

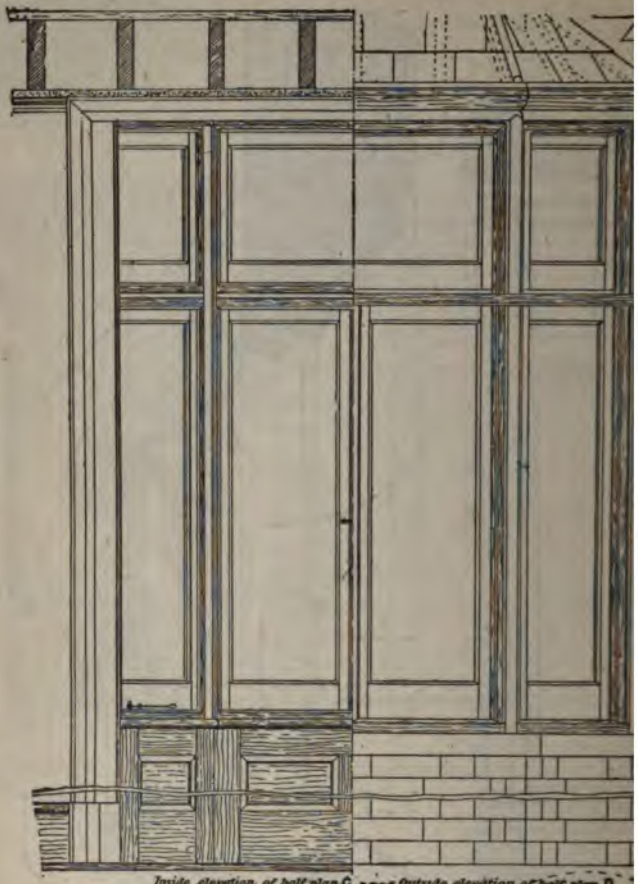


Fig. 119.

A Cased Frame Bay Window is shown in the
plan, half inside elevation, and central vertical sec
Nos. 1, 2 and 3, Fig. 119. This window is compose

three ordinary sash frames, the sills connected at the angles either by halving and screwing or by mitreing them and fastening the joint with a hand rail bolt. The heads are tied together with a short piece of 1 in. stuff screwed across the top of the joints, and the joints in the linings are covered by the mullions of the blind frame B. The latter, made 2 in. wide, forms an enclosure for venetian blinds. Boxings are formed in the elbows between the sash frames and the interior face of the wall, the front of the opening being finished off with a moulded ground and architrave. These form receptacles for the folding shutters, which are curved in plan, and when opened out convert the octagonal bay into a segmental niche. The window back and the seat beneath are also curved to parallel sweeps. The window board also follows the sweep, and is rebated to receive the shutters, a shaped bead being fixed on the soffit to form a stop at the top. Nos. 4, 5 and 6 on the same plate illustrate another method of finishing a bay window. In this case the frame is solid, and is fitted with outward opening casement lights. A blind frame is provided, and the shutters fold on to the face of the jamb and wall, the outer edges passing behind the rebated edges of the architrave; the latter is continued down to the floor, and elbow linings to correspond with the shutters are fitted beneath the window board. These are fitted to the window back in the manner indicated by the dotted lines in the plan No. 4. The section No. 6 shows the treatment of the roof of the bay, which is segmental in section and covered with shaped pan-tiles. The ribs, which are elliptic at the hips, are notched into a wall plate rest-

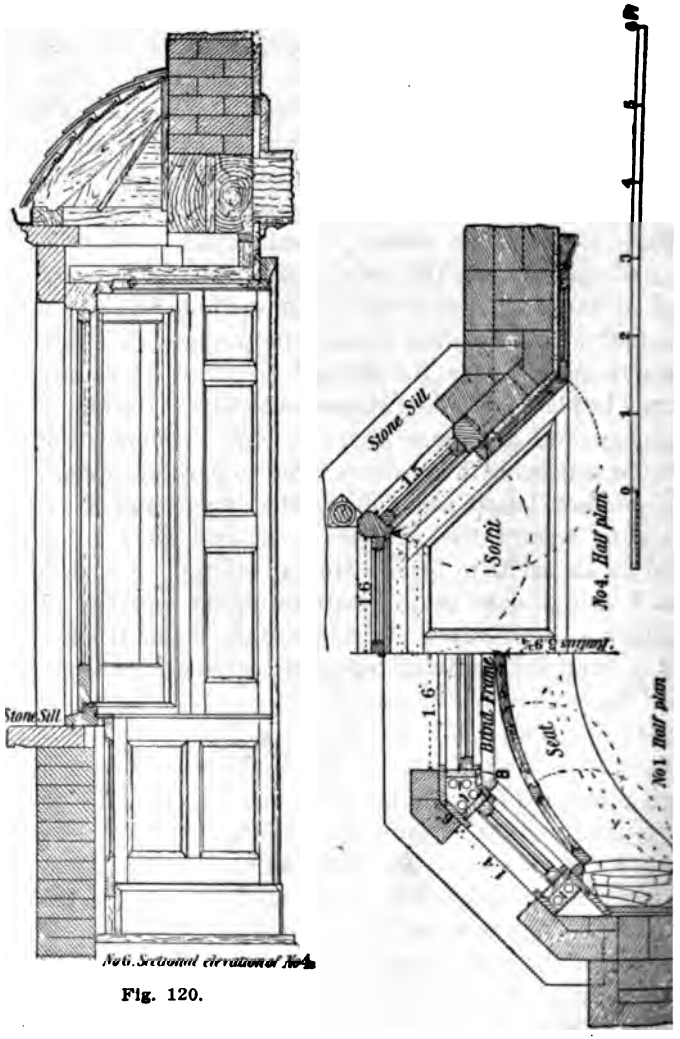
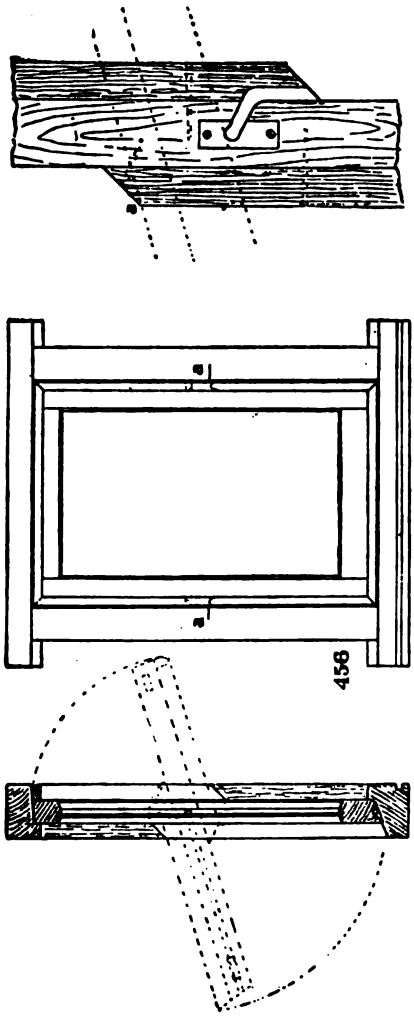

Stone Sill
No 6. Sectional elevation of No 4
Stone Sill
1.5
1.6
Sorit
No 4. Half plan
1.6
Block Frame
Seat
No 1 Half plan
1.1

Fig. 120.

ing on the stone cornice, and are nailed at the top into a shaped rib fixed on the face of the wall; the ribs are covered with weather boarding, which affords a good fixing for the tiles. The wall is carried by a breast-summer formed of two 12 in. by 6 in. balks bolted together, with spacing fillets between, and the soffit is carried by three brackets fixed to the breastsummer and the head of the window frame.

A Pivoted Light in a solid frame is shown in elevation in Fig. 122 and section Fig. 123. These are used chiefly in warehouses, lanterns, and other inaccessible positions, the lights being opened and closed either by cords and pulleys or by metal gearing. For small lights the frames are usually made out of 4½ in. stuff by 2 or 3 in. wide. Small lights are pivoted horizontally, large ones vertically. The pivot should be fixed to the frame, not the sash, and from ½ in. to 1½ in. above the centre, according to the weight of the bottom rail. The lower part of the sash should exceed in weight the upper part, just sufficient to keep it closed; its action may be easily demonstrated by inserting two bradawls in the stiles, and balancing them on the fingers. The sash is inserted and removed from the frame either by means of plough grooves in the edges of the stiles, as shown by the dotted lines in Fig. 122, or by cutting a notch through the face of the stile for the passage of the pin, which is concealed when in use by the guard beads. This latter is the better method, as it does not reduce the strength of the sash, as does the former, by cutting away the wedging. The stop beads at the sides are cut in two, one part being fixed to the frame, the other to the sash. Their joints can be at any angle



Elevation and Section of a Pivot Hung Sash. Fig. 122.

Method of Finding Cuts in Bead Fig. 123.

Fig. 124.

greater than that made by a line tangent to the sweep at the point of intersection a Fig. 124, but for the purpose of using the Mitre Block, they are generally made at an angle of 45 deg. A curved joint has no advantage over a straight one, except in being more expensive.

To Hang the Sash. Insert the pivots in the frame quite level, but do not screw them. Then with the try square resting on the top of the pins, square lines across the jambs. Then remove the pivots and insert the sash, which should be fitted rather tightly at first, and square the lines on to the sash. Return these on the edges, and keep the edge of the hole in the socket plate to the line, and the plate itself in the middle of the thickness. After the socket is sunk in, and the notches cut, test the sash and correct the joints, which should be a bare ⅛ in. clear all round.

To Find the Position to Cut the Beads. After fitting them round, remove them and open the sash to the desired angle, which should be less than a right angle, so that the water may be thrown off. Lay the beads upon the sash upside down for convenience of marking, and draw a line along their edge upon the jambs at the point where the line meets the faces of the frame; square over lines as at a a Fig. 123; the position is shown in Fig. 122, the outer dotted lines indicating the beads. Next replace the beads and transfer the marks to them, cutting them off the mitre block (remember that the mark is the longest point of the mitre). The upper portions outside and the lower inside are fixed to the frame, and these are shaded in the drawings. The remainder of the beads are fixed to the sash.

The above describes the method when the sash i grooved. Where the beads are slotted, a variatio must be made with reference to the top cut (see Fig

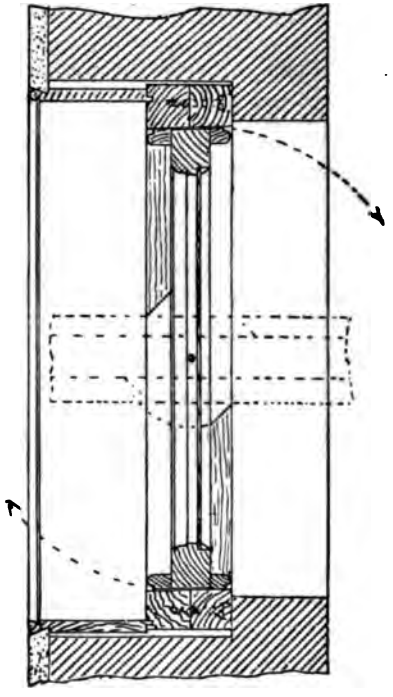


Fig. 125.

124). In this case the sash must be drawn out an rested upon the pin, then the bead laid on it an marked as before, the intersection a giving the mitr point.

A Bull's-Eye Frame with a pivoted sash is shown in Figs. 125 and 126 and enlarged detail of the joint. This frame is built up in two thicknesses, glued and screwed together, each ring being in three pieces breaking joint. The beads may be steamed and bent round, or worked on the edge of a board that has been cut to the sweep,

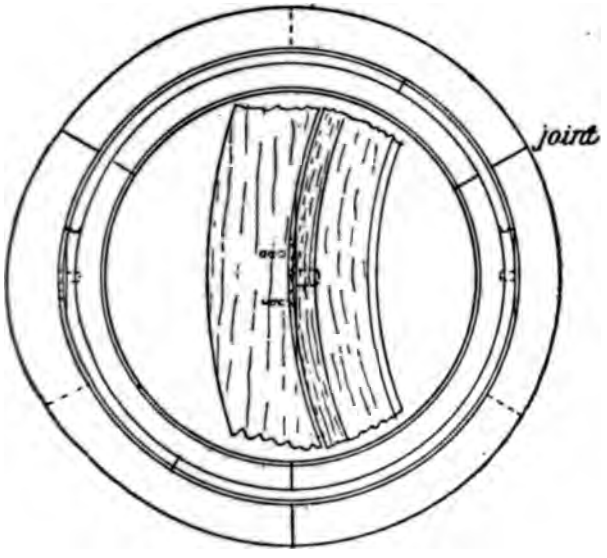


Fig. 126.

and cut off in two lengths. The sash is made in three pieces, with butt radial joints bolted together. To enable the sash to open, a plane surface must be provided at the centre, equal to the thickness of the sash and beads, as shown by the dotted lines. Having fitted the sash in, and the beads around each side, brad them tem-

porarily to the sash, lay a straight-edge across it parallel with the centre, and square up with the set square a line at each side equal in length to the thickness, then cut the pieces so marked off with a fine saw, both beads and sash, and glue them to the centre of the frame, and fix the pivots to these frames and proceed as in a square frame.

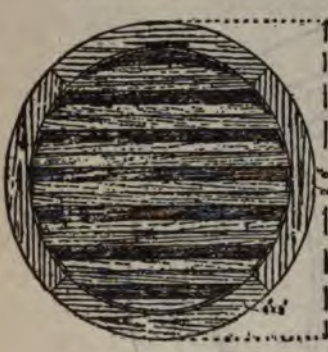


Fig. 127.

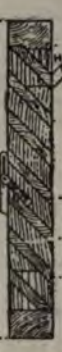


Fig. 128.

Fig. 129.

Laying Out a Circular Louvre: Suppose the frame of the louvre to be formed of four pieces, as shown at Fig. 127. These sections may be formed of one thick piece of plank, or may be built up of several thicknesses. If of one thickness, the joints may be held together with handrail screws, or dowelled and keyed. If of several thicknesses then the joints can be broken or overlapped, and the pieces either screwed or nailed together. To set out the louvre boards, make a sketch of the whole thing, full size, as shown at Fig. 127, then set up the section or side as shown at Fig. 128, then project from the quick of the bead, then draw a line C D, Fig. 129, parallel to the inclination of bevel of

the louvre boards. This will give the major axis of an ellipse. Bisect this line and draw E, F, G, at right angles to C, D, making E, F, and F G each, equal to half the radius from the centre of the frame to the quick of the bead. The ellipse C, E, D, G, may be struck by any of the methods shown. As, of course, all the louvre boards are at one angle, each forms a portion of the same ellipse. From the centre of the front edge of each louvre board, project across to the major axis as shown. Now from any of the louvre boards set off, at right angles, lines from the upper and lower surfaces as shown at H, Fig. 128, then the distance K, is the amount of projection of the lower surface in front of the upper. Taking half the distance of K, measure it off on each side of the centres 1, 2, 3, 4, 5, 6. Fig. 129, then through the points last obtained draw lines parallel with the minor axis, the upper line representing the top front board or arris of the boards, and the dotted line the bottom arris. Now measure the distances K, from C to L, and from D to M, and construct the ellipse for the underside of the boards. The following will be found a simple method for making out each louvre board: Cut a thin mould equal to one-quarter of the ellipse, the edges of the louvre boards having been planed to proper bevel, as shown at N, Fig. 128, square the centre line across the piece that has to form the louvre board and lay it on the setting out at Fig. 129, the centre line of course corresponding with C D. The quarter mould which was prepared can now be laid on the louvre board, with its curve standing directly over the development, Fig. 129, the face side of the material being of course the side marked out.

curves for the underside may be marked off on the ıses direct from the development, and the mould :n applied to the other side, taking care to adjust it the right position and to the marks made. The ends ıould be sawed and turned to the lines. The next :roceeding will be to set out the frame for the grooves; :hese are represented in the conventional sketches, 4, 5 and 6. It will be noticed from Fig. 132 that the bottom louvre board is not grooved in all round; this is a bet-

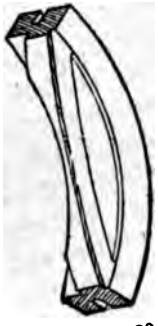


Fig. 130.

Fig. 131.

Fig. 132.

ter method than bringing it out to the front and thus destroying a part of the margin bead of the frame. The cutting of the grooves and the fitting in of the louvre boards requires careful working in order to get good joints. It must be clearly understood that Fig. 129 is not a full development of all the boards edge to edge, as that could not be represented in this space, but enough is shown to give a clear idea of how the line are obtained. The full breadth of each is represente by the dimension lines O, P, R, S, T, U, V, and fr this all the other is easy.

The Construction of Doors. **Doors** are named in accordance with their modes of construction, position, style or the general arrangement of their parts, and also the method in which they are hung, as **Battened,**

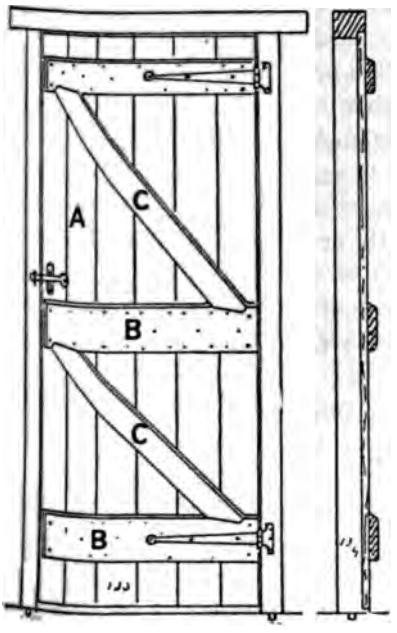


Fig. 133.

Fig. 134.

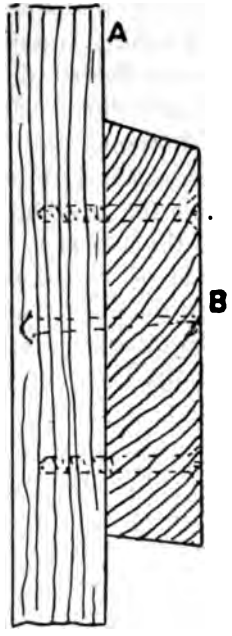


Fig. 135.

Battened Framed and Braced, Panelled or Framed, Entrance, Vestibule, Screen, Sash, Diminished Stile, Double Margin, Gothic, Dwarf, Folding, Swing, Jib, Warehouse Hung, &c. The essentials in the design and construction of doors are, for the first, that they shall have a due proportion to the building or place they

have to occupy and be suitably ornamented; in the second, that their surfaces shall remain true and their parts be so arranged and connected that their shape will be unalterable by the strains of usage and the effects of weather. The various examples illustrated will indicate the points to be considered in designing doors for sundry situations, and the methods of construction herein described will supply the necessary information to meet the constructive requirements.

Battened and **Battened Framed** and **Braced Doors** are shown in Figs. 133 and 134. These doors are suitable for positions where one or both sides are exposed to the weather. Little or no attempt is made to ornament them—economy of cost, strength and utility being the chief requirements of this class of door, which are fitted to coach-houses, W. C.'s and outhouses generally.

The plain **Battened Door** (Fig. 133) is composed of battens A, from ¾ to 1¼ in. thick, ploughed and tongued in the joints with straight tongues which should be painted before insertion, nailed to three ledges, B from 1 in. to 1¼ in. thick, usually with wrought nails long enough to come through and be clinched on the back side. The ends of the ledges are better fixed with screws, and their top edges as well as those of the braces C should be bevelled to throw off the water, as shown in the detail, Fig. 135. The lower edges may be throated or bevelled under, as shown. The braces should be placed so that their lower ends are at the hanging side, for if in the opposite direction, they will be useless to prevent the door racking. Their ends should be notched into the ledges about 1 in.

deep and 1½ in. from the ends, with the abutment square to the pitch of the brace. Narrow doors are sometimes made without braces, but they seldom keep "square." These doors are hung with wrought-iron strap hinges called cross garnets, which should be fixed on or opposite the battens, whether placed on the face or back of the door.

Fig. 136.

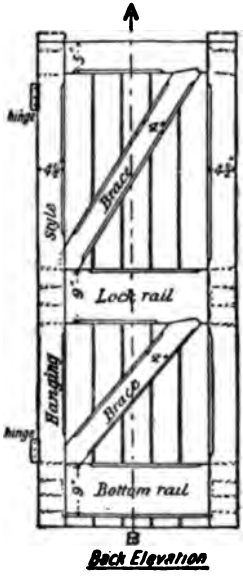


Fig. 137.

The Framed Battened and Braced Door (Figs. 136 to 137) differs from the former in that the battens and ledges are enclosed on three sides by a frame of a thickness equal to the combined thickness of the battens and ledges, so that it is flush on each side with

them. The boards are tongued into the frame at top and sides, and the ledges are framed into the s with barefaced tenons. The braces should not be t into the angle formed by the stile and rail, but be back from the shoulder about 1 in., as shown. If brace is placed in the corner, the strain thrown c has a tendency to force off the shoulder, unless the is very narrow, when the brace will be nearly upri These doors, as in fact all framed work expose damp, should be put together with a quick drying p instead of glue in the joints, because ordinary glue such an affinity for water that it will soften in d situations releasing its hold, and also be the mean setting up dry-rot in the timber. The battens in t doors should be made 1/16 in. slack for each foo width to allow for subsequent expansion, or other the shoulder will be forced off. The framework these doors is first made and wedges up, then the tens folded in and driven up into the top rail nailed to the ledges, after which the braces are tightly in and nailed to the battens in turn, and whole cleaned off together. In large gates of this scription it is usual to stub tenon the braces into rails, in which case they must be inserted first wedges up with the framing.

Framed or **Panelled Doors** are of several kinds, tinguished by the number or treatment of their pa or by the arrangement of the mouldings, as follows

Two to Twelve Panel Doors.

Square and Sunk. When a thin panel is used v out mouldings, as shown at A in the elevation diag of a **Framed** or four-panel door (Fig. 138).

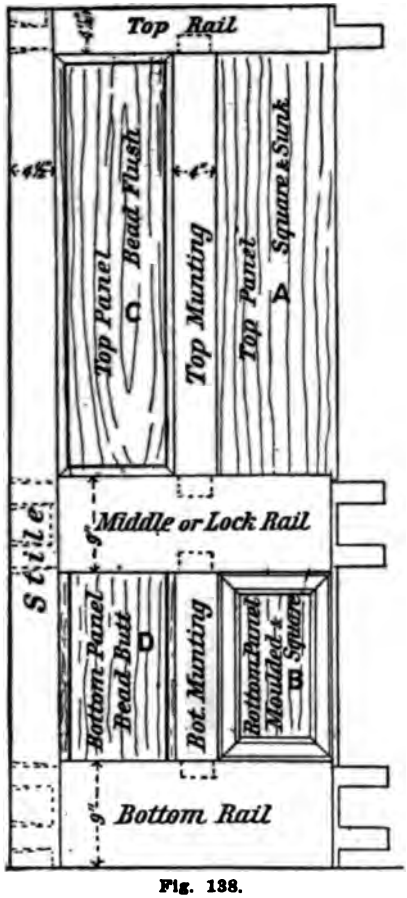


Fig. 138.

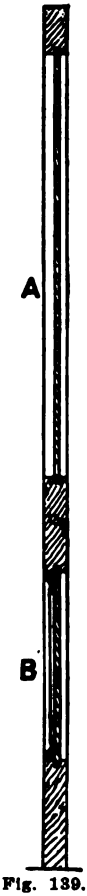


Fig. 139.

Moulded and Square. When one side of the panel is ıulded and the other plain, as at B.

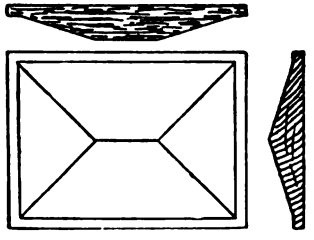
Bead Flush. When one side of the panel is flush, or ırly so, with the frame, and with a bead worked ınd the edges to break the joints, as at C.

Bead Butt. When the bead is worked only o two sides of the panel, as at D.

Raised Panel. When the centre part of the pa thicker than the margin. There are four varieti raised panels:

Fig. 140.

1. **The Chamfered.** In this the panel is cham down equally all round, from the centre to the when square, or from a central ridge if rectangul shown.



Plan and Sections of a Chamfered Raised Panel.

Fig. 142. Fig. 141.

2. **Raised and Flat** or **Raised and Fielded.** W chamfer is worked all round the edge, leaving a f the centre, as at A, Fig. 142.

3. **Raised, Sunk and Fielded** (as at B, Fig. When the chamfer starts from a marginal sinkin low the face.

4. **Raised, Sunk and Moulded** (as at C, Fig. 143). When the edge of the sinking is moulded.

Stop Chamfered. When the edges of the framing are chamfered and stopped near the shoulders.

Bolection Moulded. When the panel moulding stands above, and is rebated over the edges of the framing, as shown at Fig. 142.

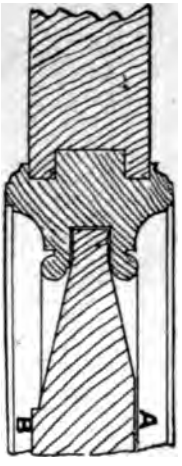


Fig. 143.

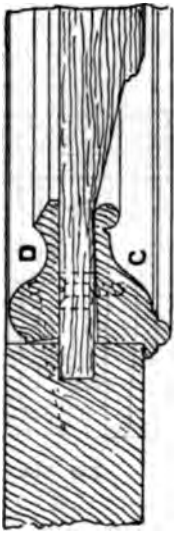


Fig. 143½.

Double Bolection Moulded. When the moulding on each side of the door is made in one solid piece, grooved to receive the panel, and is itself grooved and tongued into the framing. This variety is shown at Fig. 142.

Constructive Memoranda. The outside vertical members of doors (in common with all framed work) are

called stiles. The one the hinges are fixed to is ca the hanging stile, the one containing the lock the st ing stile. In a pair of doors the two coming toge are called the meeting stiles. The inside vertical m bers are the mountings, or more commonly munti The horizontal members are rails, respectively, frieze, middle, or lock, and bottom. The panels

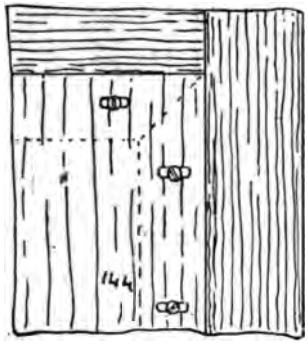


Fig. 144.

Fig. 145.

named similarly. When the grain of these run h zontally, they are said to be "laying" panels; w vertically, "upright." Doors are called **Solid-Moul** when the moulding is wrought or "stuck" in the s stance of the framing itself, as is shown at Fig. 1 and **Planted** when the moulding is worked s arately and bradded around the frame, as shown a, Fig. 143, and D, Fig. 143½. These are also cal sunk mouldings.

Bead Flush Panels are commonly made as shown at a, Fig. 146, but such panels will, unless made of thoroughly seasoned stuff, inevitably split when drying. The correct way to obtain the effect of bead flush panelling is to work the beads upon the edges of the framing, as shown in Figs. 147 and 148.

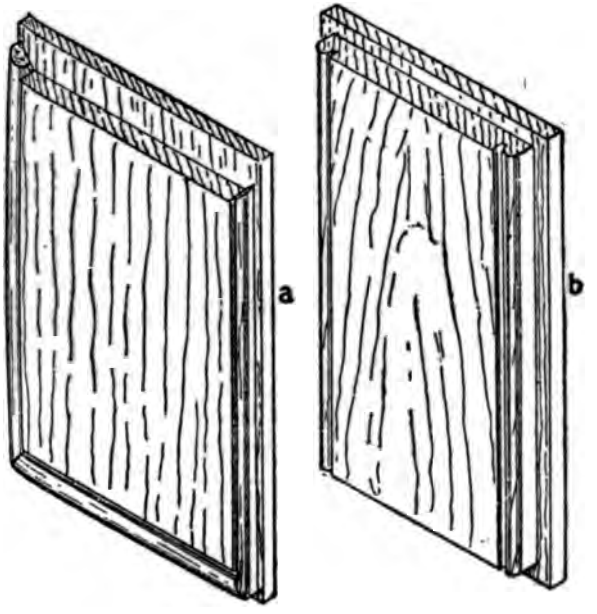


Fig. 146.

Bead Butt Panels are better kept about 1/32 in. below the framing, as a truly flush surface is difficult to prepare through the yielding of the panel, and when produced, will seldom last, as the shrinkage of the panel and frame is unequal. Planted-in "sunk" mould-

ings should be fixed to the framing, not to
as shown in Fig. 143, D; for if fixed to the p
the latter shrinks the moulding will be d
from the frame, leaving an unsightly gap.
edge of the moulding should be bevelled
shown, so that when bradded in, the fron
keep close down to the panel. As it is not

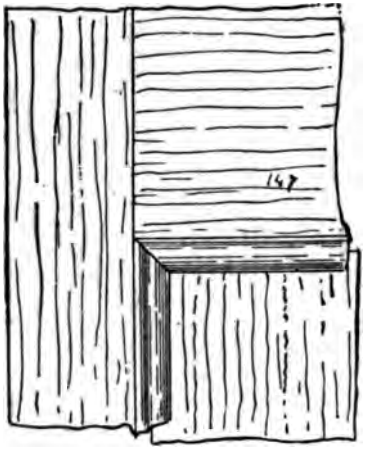


Fig. 147.

to brad polished mouldings, except in the
ferior work, these are usually glued to the
their back edges should of course be square.
should be polished before the moulding is
so that in case of shrinkage a white marg
be shown. When, however, the moulding i
thin, it is unavoidable that it be fixed to t
keep its front edge down, and to overcom

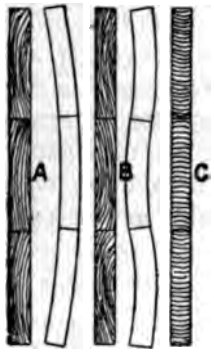
culty of shrinkage. The stiles in vertical and the rails in laying panels are prepared with a second shallow groove as shown, and the moulding, made with an extra wide quirk, is cut in and pressed back into the groove. It is glued to the panel, and shrinks with it without showing a gap. The cross pieces across the ends of the panel have their quirks shot off to the proper width, and are sprung in after the side pieces are in place. These are dowelled but are not glued, or when there is a moulding at the back, the face side is slot screwed.

Bolection Mouldings are intended to be fixed to the panels, which is rendered necessary by their great width and thickness, and they are rebated over the edge of the framing to prevent the interstices produced by the shrinkage showing. From ⅛ to 3/16 in. is sufficient for this purpose, and more should not be given or the edge will be liable to curl off. To prevent the panel being split by the fastenings when it shrinks, the moulding is fixed by slot screws, as shown in Fig. 143, the slots being cut across the grain. See the back view, Fig. 144. The moulding should also be screwed together at the mitres, and the latter may be grooved and tongued with advantage, and dropped into the panel as a complete frame, where it is fixed as described, the heads of the screws being covered by the interior moulding, which, if a sunk one, is glued to the frame, and if a bolection, dowelled to the panel, or, as is sometimes done in inferior work, bradded, and the holes filled up with colored stopping. It is not good construction to glue the moulding to the panels in any case, as the alteration of size in the latter, due to the state of the atmosphere, is very liable to cause them to

split, if fixed immovably, or when swelling, to disarrange the mitres. The bradding in of mouldings is less likely to do this if the brads are not placed too thickly, as they yield slightly to the pressure. Framing is usually grooved ½ in. deep for the panels, and the latter given ⅛ in. play sideways, but fitting close lengthways of the grain. This is sufficient for panels up to 2 ft. wide. Over that width the grooves should be ⅝ in. deep, and the panel enter ½ in. at each side. Ordinary dry stuff will eventually shrink about ⅛ in. to the foot, and will swell equally if exposed to damp. When wide panels are used they will warp less if glued up in several pieces, as the pull of the fibres is lessened by the cutting, and the effect of the warping is diminished in the same ratio as their width. Much can be done to ensure the permanent flatness of panels by paying attention to the way the boards have been cut from the tree. The direction of the annual rings on the end will indicate this, and the various pieces should have their similar sides placed together. What is meant by this will be rendered plain by an examination of Fig. 149. When a panel is glued up with the hollow or heart sides of the rings all on one face as at A, and the board warps, it will case in one continuous curve, as shown in the unshaded diagram, whilst if glued up with the heart sides reversed alternately, as shown at B, it will assume the serpentine shape shown in the unshaded diagram. Boards cut radically or with the annual rings perpendicular to the surfaces, as at C, will swell less than the others, and will not warp perceptibly.

Proportions. The size of doors depends so much upon the scale and design of the buildings they occupy, that

no definite data can be given, within reasonable limits, for important doors; but it may be pointed out that very large doors not only tend to dwarf a building or a room, but they also take up a great deal of space in opening, and the difficulty of preserving their accurate fitting increases in direct ratio with the size. The following may be taken as an indication of the more usual dimensions given to ordinary good class dwelling house doors: **Entrance Doors**, from 7 ft. to 8 ft. 6 in.



illustrating the Effect of Position on the Parts of a Panel.

Fig. 149.

high by from 3 ft. to 4 ft. 6 in. wide, 2 to 2½ in. thick. **Reception Rooms**, 7 ft. by 3 ft. 3 in. by 2 in. **Bed-Rooms**, 6 ft. 8 in. by 2 ft. 8 in. by 1½ in. Details of interior doors; stiles and top rails, in common work, out of 4½ in., muntings and frieze rails 4 in., middle and bottom rails 9 in. Superior doors vary much, but gen-

erally stiles and rails are somewhat wider th above, muntings and frieze rails narrower. He lock rail usually 2 ft. 8 in. to its centre. This i venient height for the handle, which is generally in the middle of depth of rail. When an entran is approached from a step the middle rail is kep 6 in. lower, to bring the height of the hand venient.

Common Doors, both internal and external, ar of "yellow pine" or Georgia pine throughout. ter class of interior doors have yellow pine fran white pine panels. The latter wood should used for external work, as it is far too soft a not stand wet. **Superior Internal Doors** are throughout of Honduras mahogany, black wal oak; also of pine and baywood, veneered with mahogany. **External Doors** of oak, teak, waln pitch pine.

In constructing doors of any of the above me figure woods, great attention must be paid to rangement of the members, so as to balance the and this may also well be studied in the conver the plank. For instance, two stiles, each havi nounced figure at one end, and the other end should have the figured ends placed at the botto gives the effect of solidity, whilst the reverse make the door look top heavy. Similarly the rails should be plain, the lower figured. It n understood the above only applies when the wo mixed lot. When the wood is handsomely throughout, the point of most importance is th of its position upon the figure, and this is so gre

in some of the light-colored woods, wainscot and bay-wood for instance, a piece that in one position will appear richly figured will in another show quite plain and dull. The best way to judge the effect is to prop the pieces up in the approximate positions they will occupy when finished, facing a top light. Then when standing a few feet off, the play of light on the fibres will be observed. Deep-colored woods, such as teak and Spanish mahogany, may have their figure brought out by slightly oiling them, which will facilitate their arrangement. Panels also require balancing, the more

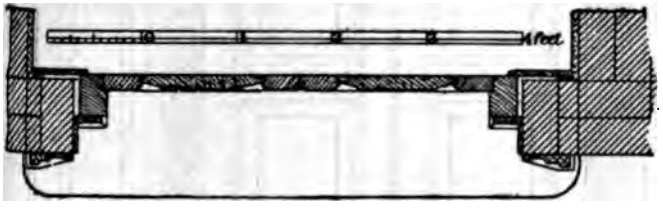


Fig. 150.

heavily marked ones being placed below plainer ones, and symmetrically arranged, either in pairs, or figured in the centre and plain outside. In all cases where the figure is coarse, taking a truncated elliptic shape, the base or wider part should be kept downwards. The panel at B is upside down from an artistic point of view. This arrangement is known in the workshop as "placing the butts down," although as a matter of fact the width of the figure is not due to its being towards the butt end of the tree, but merely to the accidental position the surface of the board occupies with relation to the annual rings, which are more or less

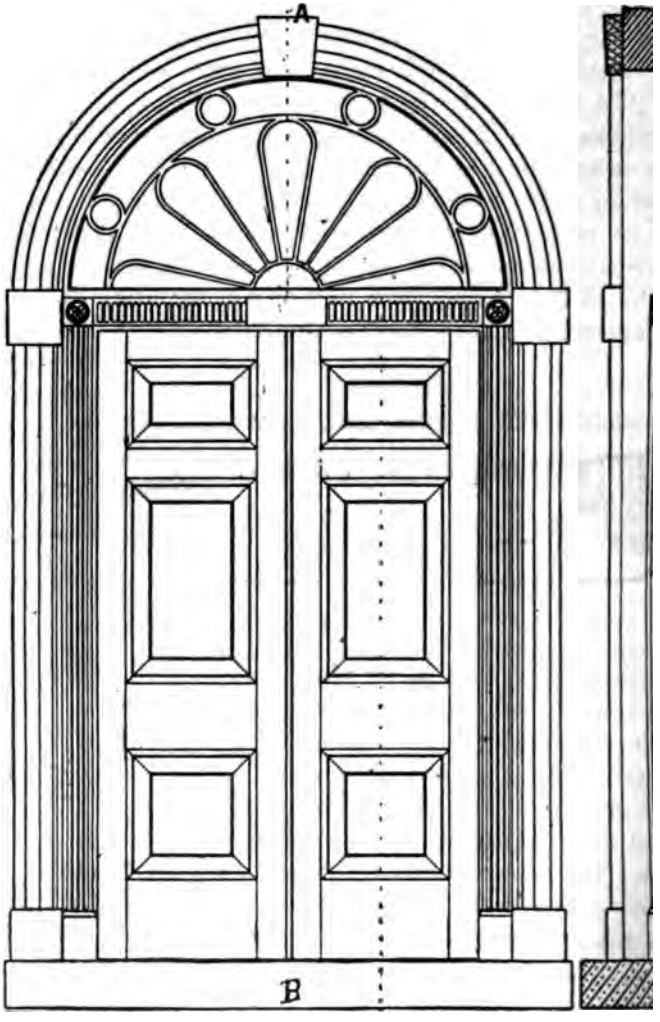


Fig. 151.

Fig.

waved in length, due to crooked growth, and the board passing through them in a plane, their edges crop out on the surface in irregular elliptic shape.

Double Margined Doors are wide single doors framed to appear as pairs of doors. They are used in openings too wide proportionately for a single door, but where half the opening would be rather small for convenient passage. Figs. 150 to 154 show elevation and sections of a **Double Margined Entrance Door,** typical of the style in vogue in the latter part of the eighteenth and early part of the nineteenth centuries.

These doors are made in two ways. In the earlier method the central imitation stile, which in this case is really a munting, is made in one piece and forked over the top and bottom rails, which are continuous. The intermediate rails are stubtenoned to the central, and through tenoned and wedged to the outside stiles, but unless the stub tenons are fox-wedged, the shoulders are very liable to start, for which reason the method of construction now to be described is generally preferred. The door is composed of two separate pieces of framing, each complete with two stiles and a set of rails that are tenoned through and wedged up. The two portions are then united by a ploughed and tongued and glued joint, which is hidden by a sunk bead in the centre, as shown in the diagram, Fig. 155, and the parts keyed together with three pairs of hardwood folding wedges. The door is sometimes further strengthened by having flat iron bars sunk and screwed into the top and bottom edges. The actual process of putting the door together is as follows: After the various rails and panels have been duly fitted and marked,

each leaf is taken separately and the stiles knocked on. The one intended for the meeting stile having been

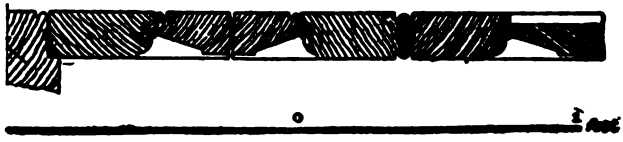


Fig. 153.

Fig. 154.

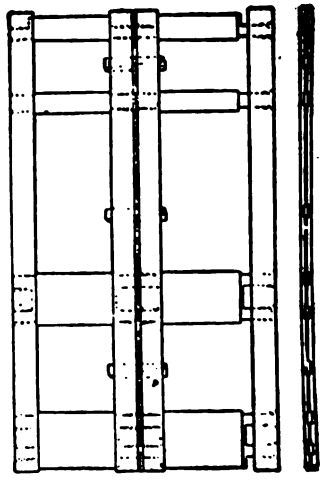


Fig. 155.

Fig. 156.

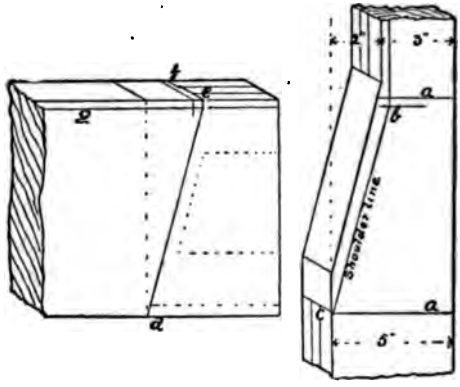
glued, is cramped up and wedged. Then the meeting stiles are made to a width, grooved, jointed, and re-

bated for the beads, as shown in the detail, Fig. 150. The ends of the tenons and wedges should be cut back ⅛ in. to prevent them breaking the joint when the stile shrinks. The mortises for the keys will have been made when the mortises for the rails were done, and cross-tongues are next glued in, the joint rubbed, the two stiles pinched together with handscrews, and the oak keys, well glued, driven in. At this stage the frames are stood aside to dry, after which the projecting ends of the keys are cut off, the panels inserted, and the two outside stiles glued and wedged in the usual manner. After the door is cleaned off, the grooves to receive the beads are brought to their exact size with side rabbit and router planes. Should iron bars be used, they are inserted in grooves made after the door has been shot to size. The bars should be about ½ in. shorter than the width of the door, so that the ends are not visible.

Diminished stiles are sometimes cut out in pairs from a board or plank. When this is done, the back or outside edge is shot straight and the setting out made thereon, the two portions being gauged to width also from the back, but the method more suitable for machine working. Here the stile may be cut parallel to the full width, the face edge shot in the usual way and the setting out made upon that, the diminish being gauged from inside. In this method the mortises are made before the diminished part is cut out, to render that operation easier for the machinist. He should not, however, mortise right up to the sight lines on the diminished part, because if the chisel is at all out of upright when the waste is cut away, the mortise will be

found beyond the sight line, which will be a serious defect.

To Set Out the bevelled shoulders of the stile and rail. Taking the stile first, having as described in the first method gauged and faced up the inside edges, and set out the width of the rails and mortises on the back edge, square over on each side the sight lines of the middle rail as at a a, Fig. 156. Then draw a second

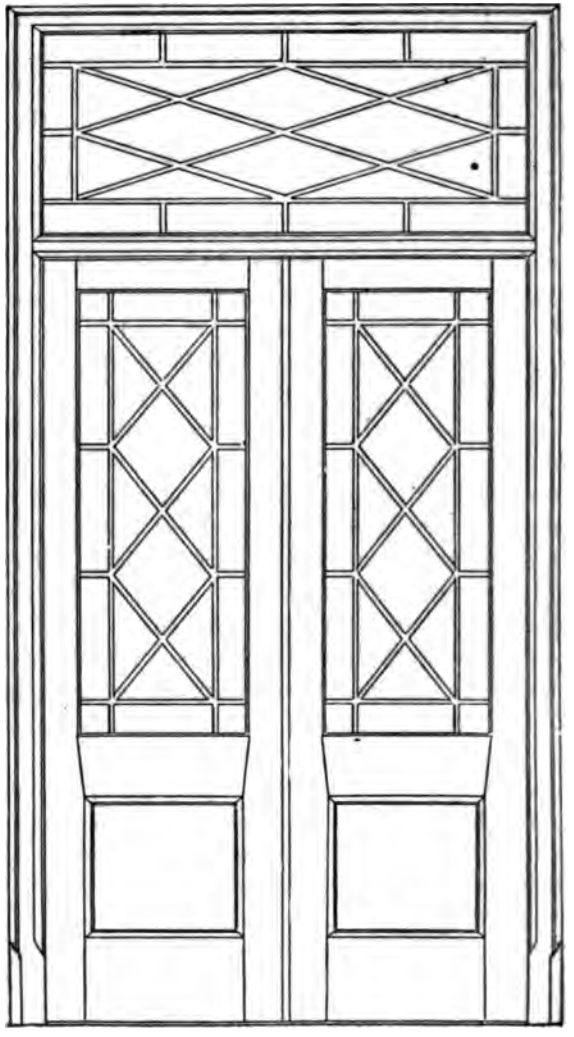


Stile and Rail of a Diminished Stile Door.
Method of Obtaining Shoulder Lines.
Fig. 156½.

line representing the depth of sticking of the rail on the face side, and the rebate on the back side, as at b. Next run gauge lines down on each side of the diminished part as working lines of rebate and sticking, and from the points of intersections of the stickings and rebates respectively, draw in the shoulder lines to the sight line of the lower edge of the rail at c. The only difference to be made when the stile is prepared by

the second method is that the sticking and rebate gauges would be run from the original face edge instead of the actual diminished edge, and as before stated, the sight lines would be marked on the face edge instead of the back, and squared down to the intersections.

To Set Out the Rail. Mark on the bottom edge the "width" or sight lines of the widest part of the stiles. Square this point on to the upper edge as shown by dotted line in the sketch, Fig. 156, and set off therefrom the amount of the diminish on the stile, as shown by the dotted line on the stile in the example: this is 2 in. This line, knifed in on the edge, is the "sight line" of the upper part of the stile. Again set off beyond this line the amount of the sticking and rebate shown in the sketch by the lines e and f. Next run the sticking and rebate gauges on front and back sides, as shown at g, and square down the lines e and f to meet them. Then draw the shoulder lines from the intersections to the point d on each side. Having thus found the shoulder line upon one rail, bevels may be set to them and used to mark any number. A contrivance sometimes used when a large number of similar shoulders have to be set out is shown in Fig. 157. This is known as a **Shoulder Square.** It consists of an ordinary set square provided with a movable fence or bar B, which is slotted to pass on both sides of the square, and is pivoted near the right angle. A set screw near the outer end of the bar passes through a concentric slot, and fixes the fence in any desired position. The pivot works tightly in a small slot to allow the lower edge of the bar to enter the right angle, and the outer edge of the



A PAIR OF VESTIBULE DOORS. (*Eighteenth Century Style.*)
FIG. 157.

square is also made a concentric curve to permit the easy passage of the end of the bar. The theory upon which the action of the tool is based is that the angle between the parallel bar B and either of the edges of the square is the complement of the remaining angle, the two combined forming a right angle which is the

An Adjustable Square for Bevel Shoulders.

Fig. 157½.

desired angle between the edges of a rail and stile. Its application is shown in the upper part of the figure, a being the rail, b the stile. Either a rail or stile is first set out as described above, the edge of the square set to the shoulder line, and the bar brought up to the face of the work and fixed with the set screw when it

is ready for application to the other piece. Th ing upon a diminished stile should not be m continued on to the shoulder, and the rail scr it, which will prevent an open joint occurrin the rail shrink. When doors, after knocking are stored for a second season, a slight differ have to be made in the setting out of the sho the middle rail. The wider part of the stile w more than the narrow part, and consequent shoulders are set out accurately at first as above, when they are refitted the shoulders found short at the lower ends. To prevent th about 1/32 in. extra on the lower part of the at each end of the rail.

A Gothic Door of the Tudor period is show elevation in Fig. 158 and section in Fig. 159. is four-centred. The upper panels are pierced and the lower ones carved drapery. The m in this type of door are invariably stuck s those on the stiles stopped at the sight line rails. The mouldings on the latter are also fr stopped at the muntings as shown especiall earlier work. Many of the doors, however, o dor period have the upper ends of the munting In modern work of this style, when the moul not stopped, it is usual to scribe them at the tion. Chamfers, however, are always stoppe tain a square-built shoulder for the muntin shoulder scribed over a chamfer soon get through the shrinkage.

Mediaeval doors were always constructed but **pitch** or **Georgia pine** is now much use

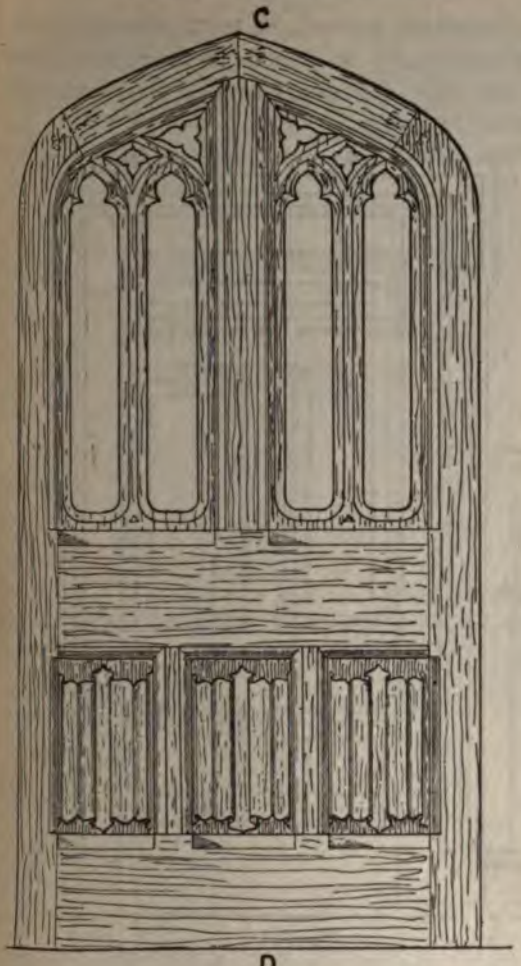


Fig. 158.

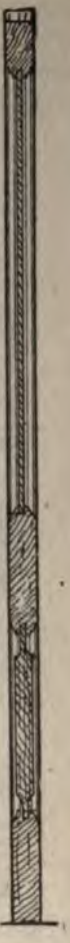


Fig. 159.

tyle of work. The older examples are mortised, ten-ned, and pinned together, wedging and glueing be-g a modern invention. The joints at the head are

usually slip tenons, pinned, or with dovetail keys serted. These joints in a modern door would be cured either with a hammer-headed key or hand bolts.

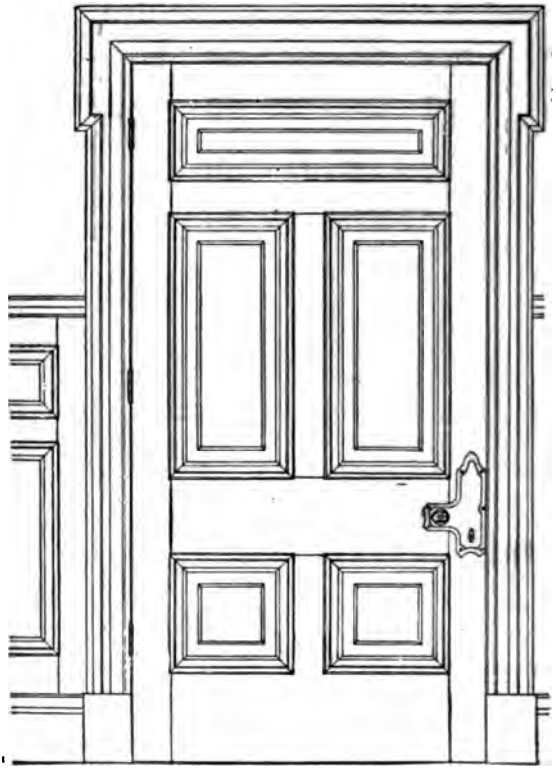


Fig. 160.

Fig. 160 shows the elevation of a superior five-p elled interior door with its finishings. Fig. 161 sh a vertical section through the opening, and Fig. 16

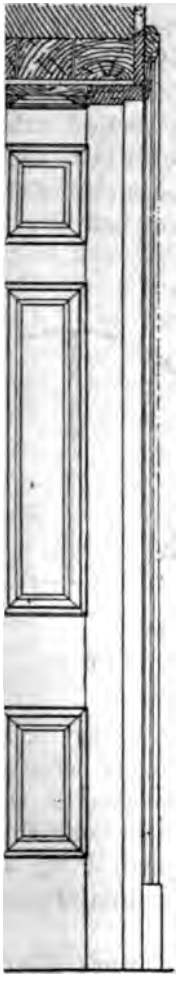


Fig. 161.

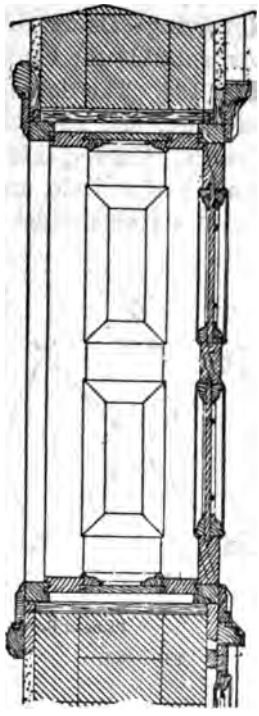


Fig. 162.

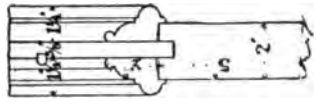
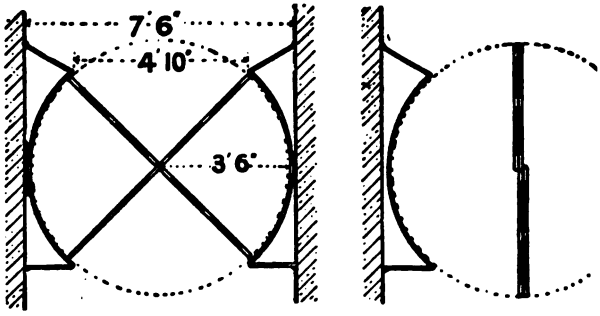


Fig. 163.

ıowing in outline the framed soffit lining. Fig. **n enlarged** section of one stile and part of **ɔuldings**, etc.

Revolving Doors.—An arrangement of ve doors, suitable for banks, hotels, etc., is shown i in Fig. 164. The doors are arranged at right an each other, and revolve around a vertical axis turn-stile. Curved side frames, each a little wide a quarter of a circle, are fixed on each side of th way. A suitable width for the doors is 3′ 6″. T



Plans of Revolving Vestibule Doors.

Fig. 164. Fig. 165.

vantages of such an arrangement is that it is less and draughtproof, the latter feature being ob by having an india-rubber tongue fixed in the edge of each door. The doors are so hung that nate doors can be folded back against the ad ones (Fig. 165), and thus give an uninterrupte sage when required.

Other Panelled Framing.—Framework filled tirely with wooden panels, or with wooden pa the lower part and glass in the upper part, is a quired in the fittings for offices, for school par

and for screens in churches, business premises, etc. The arrangement of the framing is similar to that of doors, and the same terms are used to describe the various parts, the only difference being the proportions of height and width; these are, of course, governed by special requirements.

Superior Doors.—In superior work, where the doors and surrounding framework are made of ornamental hardwood, it is often necessary to construct a door which shall be of one kind of wood on one side of the door and an entirely different kind on the other side. This would be necessary, for example, with a door opening from an entrance hall fitted entirely with oak into a room, the fittings of which must all be of walnut or mahogany. Such a door may be constructed in two thicknesses, each of the respective kind of wood, and each of a thickness equal to one-half of that of the finished door. The two parts are then secured together by tapering dovetailed keys, and the edges of the door are afterwards veneered to match the side of the door to which they correspond. Figs. 166 and 168 give details of this kind of door.

Grounds.—The architraves surrounding an opening are nailed to the lining, or where possible to the frame. In the best class of work, however, it is usual not to fix the door frames until the plastering is finished. Rough wooden battens or **Grounds**, of thickness equal to that of the plaster, are fixed to the walls around all door and window openings. These serve as a guide to the plasterer, and the door frames and the surrounding architraves are secured to them. When it is not desirable to have any nail holes visible in the

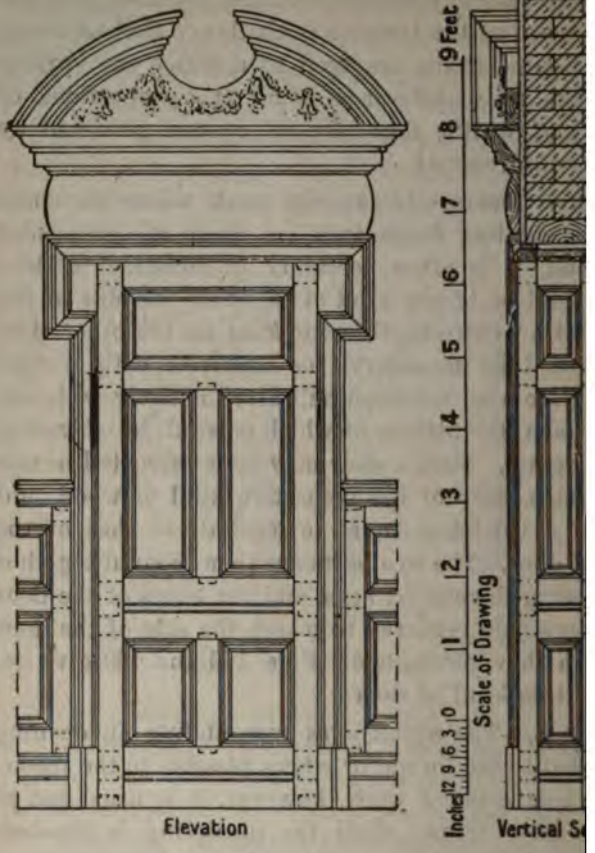


Fig. 166.

Fig. 16

Fig. 168.

finished surfaces, the door frames and architraves are fixed by screws.

The fixing of the architraves around such a doorway affords a good example of **Fixing by Secret Screwing.** The mitres of the architraves are first glued and secured with dovetail keys or slip feathers. Stout screws are turned into the grounds about 12″ apart, being left so that the head of the screw projects about half-an-inch in front of the surface. On the back side

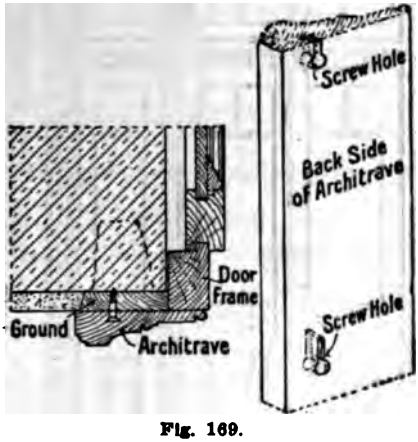
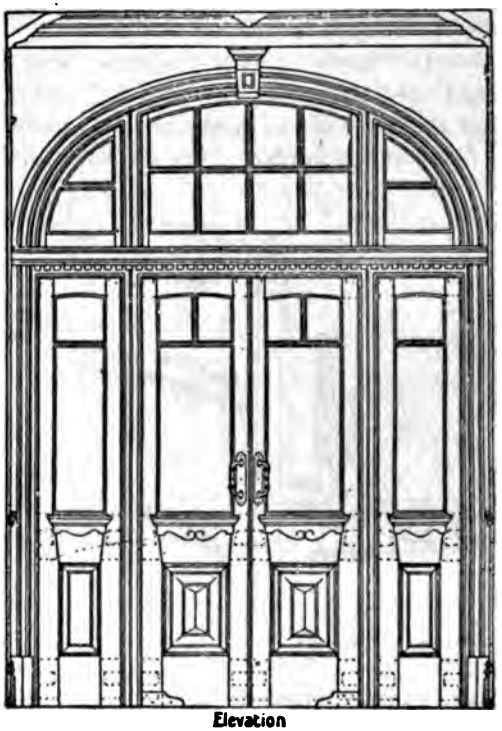


Fig. 169.

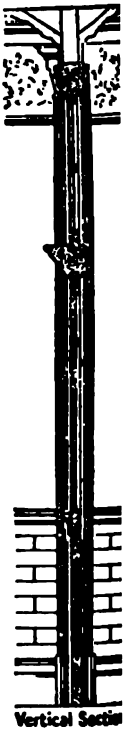
of the architrave, exactly opposite the screw heads, small holes—equal to the size of the shanks of the screws—are bored; and about three-quarters of an inch below these, larger holes—of size equal to the heads of the screws—are bored. Each small hole is connected to the large one adjacent to it by a slot, the depth of which is slightly greater than the projection of the screws. The architrave is fixed by placing

it against the wall with the larger holes fitting on the screws, and then carefully driving it down so that the heads of the screws hook into the fibres behind the



Elevation

Fig. 170.



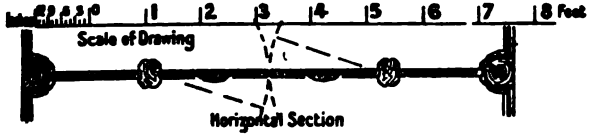
Vertical Section

Fig. 171.

slots. By placing the screws so that they are slightly inclined, the tendency is to draw the architraves close to the wall. Fig. 169 shows the explanatory detail.

The above remarks upon door frames, linings, etc apply especially to the doors of dwelling-houses. Do

frames for warehouses, workshops, outbuildings, etc., do not as a rule require linings or architraves, a small fillet being nailed into the angle between the door frame and the wall instead. Vestibule doors are often hung to swing both ways, and the door frames have a hollow rebate or groove in the middle of the width of the frame, to receive the rounded edge of the door (Figs. 170, 171 and 172). Many of the heavier kinds of framed and ledged doors are not provided with wooden frames but are hung with bands and gudgeons, or arranged to run on pulleys as described elsewhere.



Details of a pair of Vestibule Doors with Side-lights.

Fig. 172.

Fig. 173 shows an ordinary sash door with three panels below. Fig. 174 shows a section of door and frame. Fig. 175 shows plan of door and part of cross section of frame. Fig. 176 shows the height and width rod of a door, which guides the workman in laying out his work.

External Doors are invariably hung in **Solid Frames.** Internal doors, chiefly to build up casings or **Linings,** of comparatively thin substance. In certain positions, such as vestibules and shop-fronts, where there are no wall openings to line, solid frames are also used for

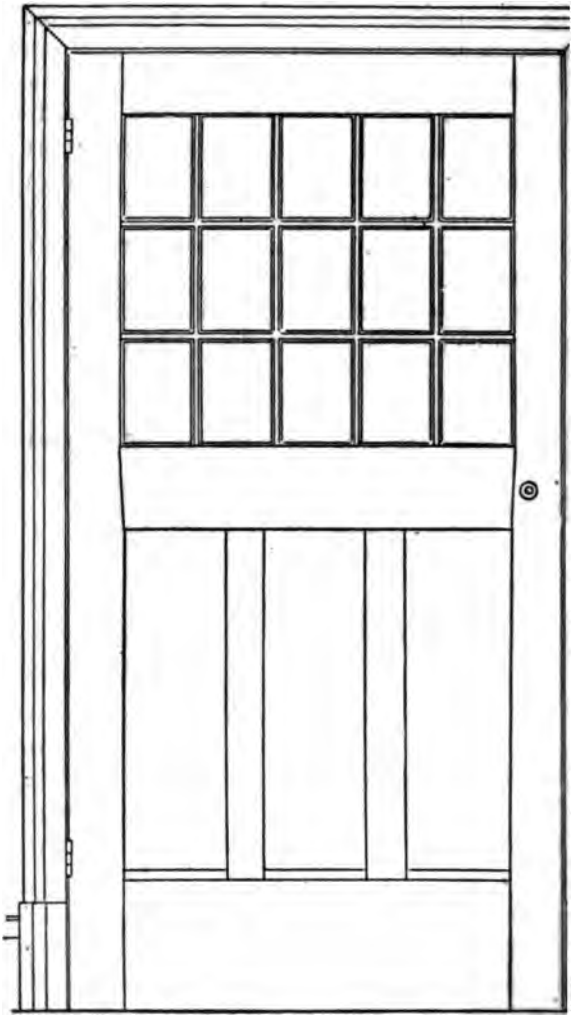


Fig. 178.

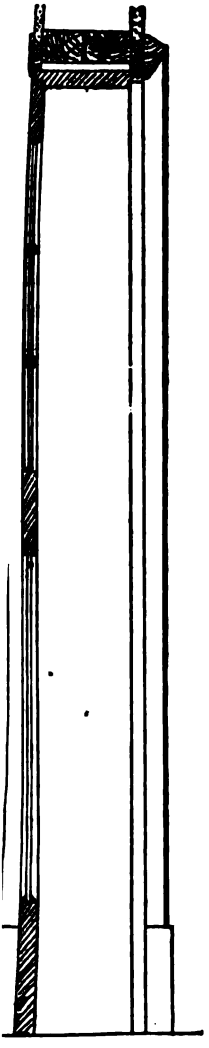


Fig. 174.

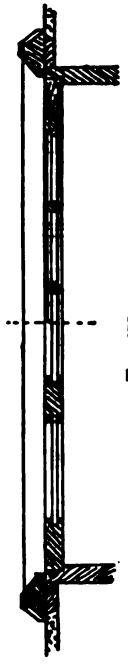
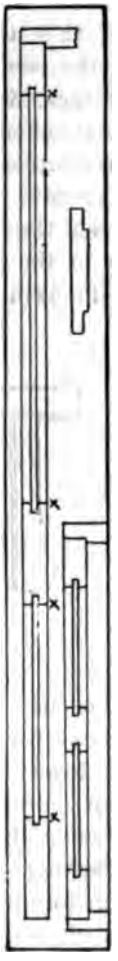


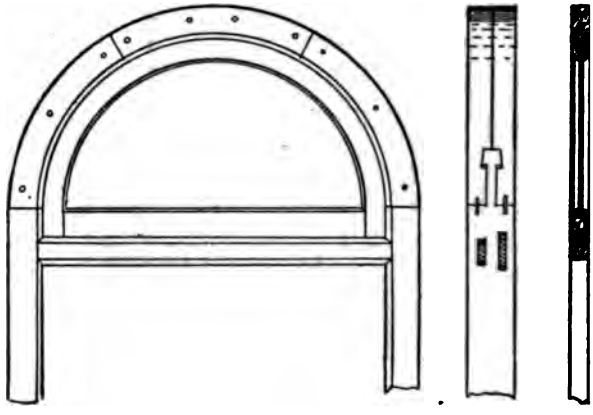
Fig. 175.



Height and Width Rod of a Door.

Fig. 176.

layer being in two lengths, the other in three, s
to break joint. This is both a strong and econor
way of forming a head, because the grain is less
across than it would be in a head cut out of one t
ness, and the labor of rebating is also dispensed
the inner ring being kept back ½ in. to form
bate. The head is fastened to the jambs by ham
head tenons and shoulder tongues, as shown in
182, and double tenons are used for the transo



A SEMI-HEADED SOLID FRAME.

Fig. 181. Fig. 182. Fig.

avoid cutting the root of the head tenons. The
som is better kept about 3 in. below the springi
shown, to ensure a strong joint. But if the exige
of the design necessitate its being placed at the sp
ing, then the jamb should be carried above the sp
ing and a portion of the curve worked upon it, be

ade in two lengths, jointed at the crown, and fas-ıed with a handrail bolt. The horns are taken out 'el at the springing line, and the back is made ıghly parallel to the shoulders for convenience in ng. When the frame is 4 in. and upwards in thick-s, double tenons should be used, as shown in Fig. '; and if the position in which the frame is to be ed does not admit of the horns being left on, the rtises should be haunched back, as shown in Fig.

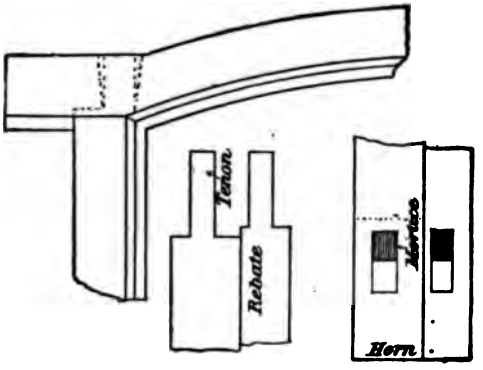
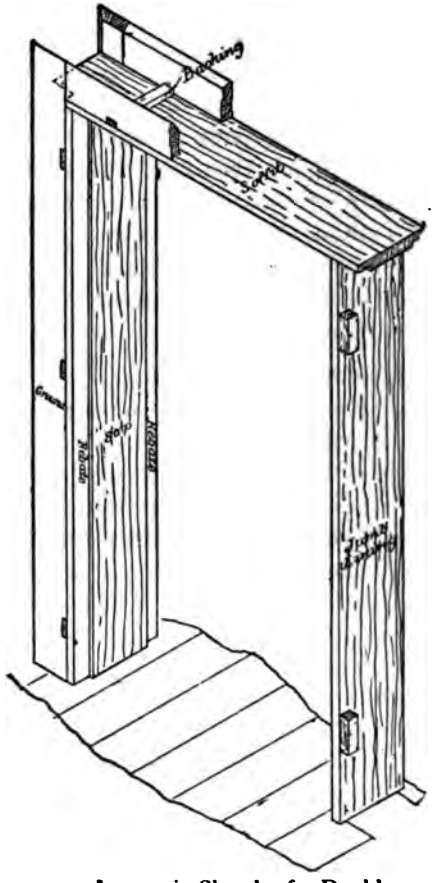


Fig. 178. Fig. 179. Fig. 180.

although the horns would not be cut off until the ne was fixed, as they would be required for the ɔose of cramping up the frame.

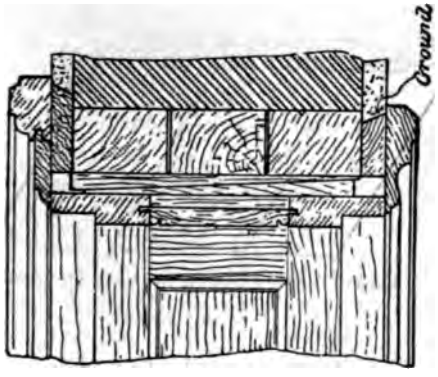
Semi-headed Frame may have its head cut in two hree lengths and bolted together, but is frequently ; up as shown in Figs. 181, 182, 183. The jambs transom are worked solid, but the head is formed wo thicknesses glued and screwed together, one



Isometric Sketch of a Double Rebated Set of Plain Linings with Double Set of Grounds.

Fig. 184.

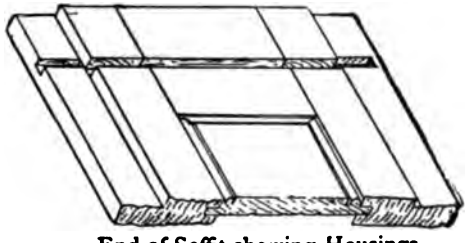
unds.—Figs. 188 and 189 are light frames form-
boundary to all openings in plastered walls, their



Head of a Framed Jamb Lining.

Fig. 185.

e being to act, as the name implies, as a ground-
'or the linings, architraves, &c., and also as a

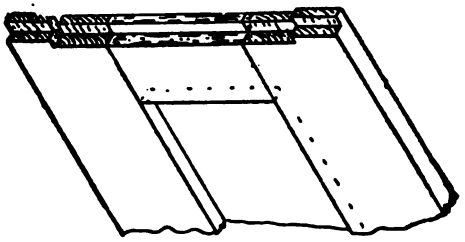


End of Soffit showing Housings.

Fig. 186.

and gauge for the thickness of the plaster.
re either bevelled or grooved on the back edges
ı a key for the plaster, and should be framed up

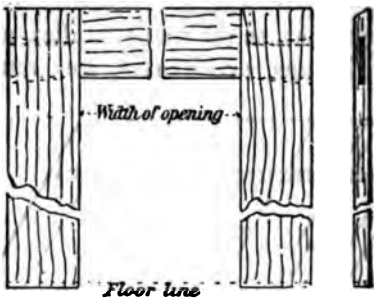
perfectly square, and with faces and inside edges true, straight and square, to ensure good fittings in the finishings. They are fixed by nailing to plugs or wood



End of a Jamb Lining showing Tongues.

Fig. 187.

bricks in the walls, and should be secure, plumb and out of winding. They are usually prepared out of 1 in.



Elevation and Edge View of a Set of Grounds.

Fig. 188. Fig. 189.

stuff, their width depending upon the width of the architraves, which should overhang them about ⅜ in. More cover than this is not advisable, or the fixing for

the outside of the architrave will be lost, and for the same reason much bevel should not be given to the back edge. A ¼ in. will provide quite sufficient key for the plaster, and also, as the grounds have to be bevelled before glueing up, a very thin edge is liable to be crushed in cramping them up. The sets of grounds on each side of an opening are connected across the jamb by 1 and 2 in. slips called Backing pieces, dovetailed, and nailed to the edges. Grounds

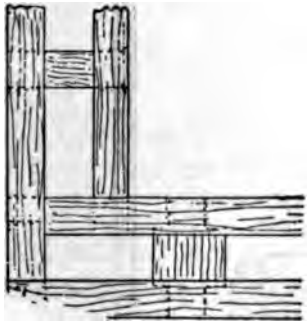


Fig. 190.

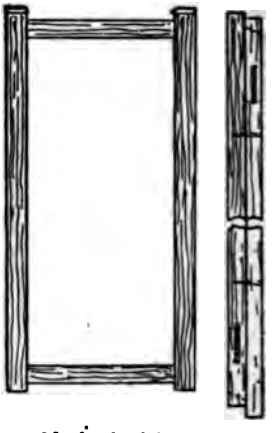
are, however, very often fixed flush with the brickwork, which does not permit of the use of backings; it is a very inferior method, the linings either touching the walls, or if made smaller, having to be fixed with folding wedges and firring pieces, which do not afford so firm a fixing. When the architrave is of such width that the sides of the ground are required more than 5 in. wide, it is not advisable to make them in one piece, because from their position they are very liable to cast, and so spoil the appearance of the finishings. In such cases, the grounds should be formed as skeleton frames

with rails and stiles, where required from 3 to 5 in. wide (see Fig. 190).

Grounds are sometimes moulded or beaded on their inside edges, as in Fig. 191. They are then called **Architrave Grounds** or **Moulded Grounds**, and are fixed to the edges of the linings, which in such cases must

A Moulded Ground.

Fig. 191.



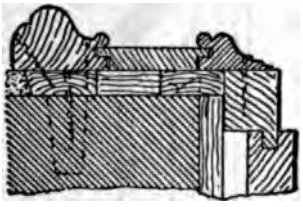
Method of Arranging "Grounds" for Glueing Up.

Fig. 192.

be fixed first. The moulded ground is more frequently used in window and shutter openings than in door openings. All joinery finishings are fixed to grounds, but these are seldom framed, except in the cases of door, window and shutter openings, all other work being fixed to rough grounds, which will be illustrated in their appropriate place.

Framed Grounds are usually wedged up and sent out from the shop in pairs, as shown in Fig. 192, Fig. 193 being an edge view to larger scale. Two sets are lightly nailed face to face, and with heads reversed, in which position they can be knocked apart and glued, then cramped, squared, and wedged up with facility.

Architraves are the moulded borders or frames to window or door openings. When square at the back, as in Fig. 191, they are termed **Single-faced**; when moulded at the back, as in Fig. 185, **Double-faced.** No

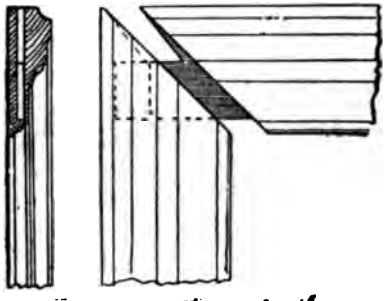


Framed Architrave and Grounds.

Fig. 193.

architrave should be made wider than 6 in. in one piece, as there is great danger of its splitting when shrinking, being fixed necessarily at both edges; but when this size is exceeded, the moulding should be made up of two or more members, grooved and tongued together at some convenient point, as shown in Figs. 185 and 193, the latter being an example of a very wide so-called **Framed Architrave**; then, if fixed at both edges, it will be free to shrink in the middle.

Heavy Architraves are ploughed and cross ton in the mitres, and in some cases framed or stub mort and tenoned, as shown in Figs. 194 and 195. T are glued and fixed with screws turned in from back. Small handrail bolts are also used to dra the mitres in thick mouldings. Sets of architrav treated are framed up on the bench, provided stretchers at the bottom end, and braced to pre

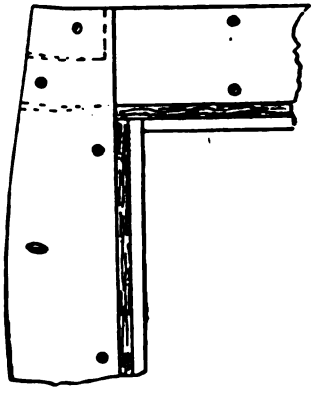


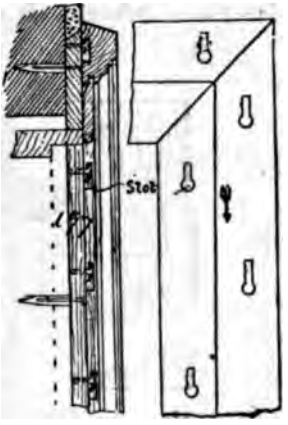
An Architrave Tenoned and Mitred.

Fig. 194. Fig. 195.

racking during transit, and are fixed complete. Sm ones are mitred and fixed piece by piece. In the class of polished work, secret fixings are used fo curing the architrave to the grounds. These are sh in Figs. 196, 197 and 198. A number of stout sc are turned into the grounds with their heads pro ing uniformly about ¼ in. Corresponding holes bevelled slots are made in the back of the moul which is dropped on the screws, and carefully d

down in the direction of the arrow. The architrave should be driven on to the screws dry in the first place; two workmen being employed in the operation, one upon a scaffold carefully drawing down the architrave





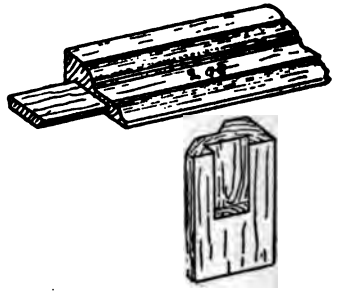
Elevation of Back of Architrave. — Section of Architrave. and Elevation of Face of Grounds.

Fig. 198. Fig. 197. Fig. 196.

equally on each side; the other pressing the moulding tightly towards the grounds, and striking a piece of wood with a heavy hammer over each screw as his fellow strikes the top. After being duly fitted the architrave may be knocked up again, and the front edges only lightly glued before replacing.

Foot or **Plinth Blocks** are used at the bottom of all architraves in good work, and are secured in two ways

(see Figs. 199 and 200). The latter is the better way, as there is less difficulty in fitting the shoulder, and also less danger of splitting the plinth, when driving the dovetail tenon in; this is glued and secured with a screw turned in the back. A handscrew may be used to grip the sides of the block whilst driving the latter on to prevent its splitting.



Method of Fixing Plinth to Architrave.

Fig. 199. Fig. 200.

Door and Jambs Complete. Figs. 201 and 202 show a door, with jambs and linings complete. The details for constructing and fastening in place are all shown. Each member of the door is named, also base and grounds.

Figs. 202 to 220 show a number of typical doors, some of which will be found suitable for any particular purpose.

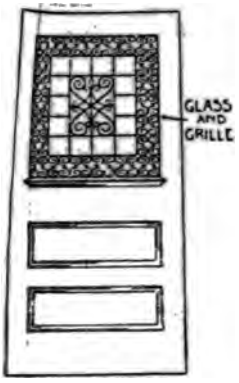


Fig. 209.

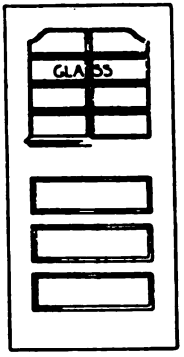


Fig. 210.

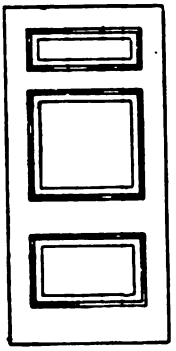


Fig. 211.

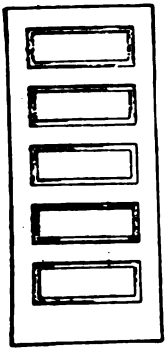


Fig. 212.

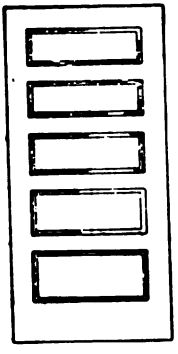


Fig. 213.

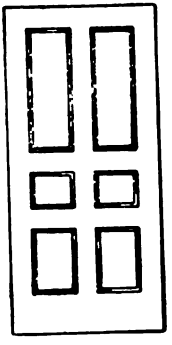


Fig. 214.

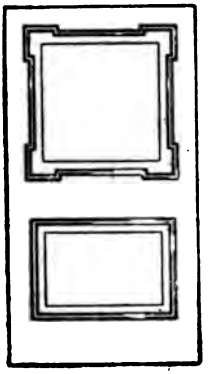


Fig. 203.

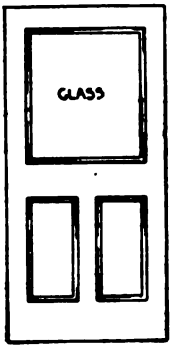


Fig. 204.

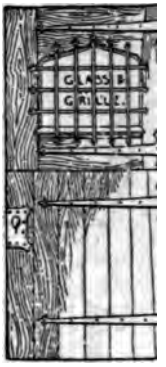


Fig. 205.

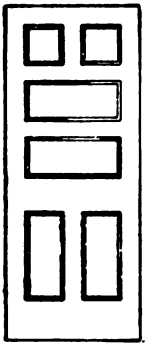


Fig. 206.

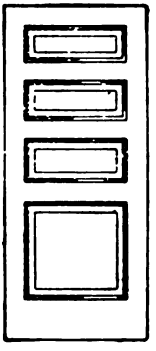


Fig. 207.

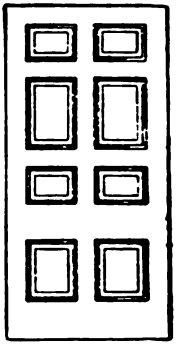


Fig. 208.

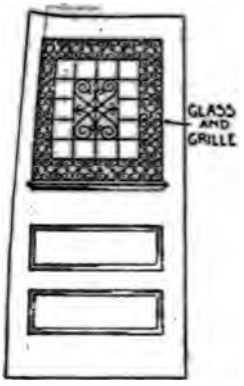
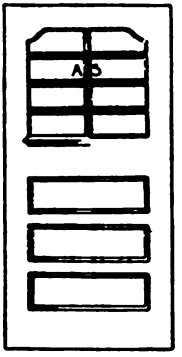


Fig. 209.



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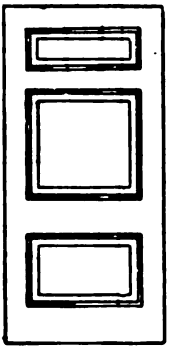
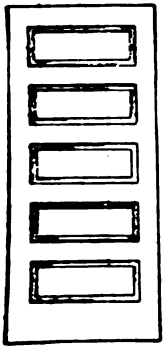


Fig. 211.



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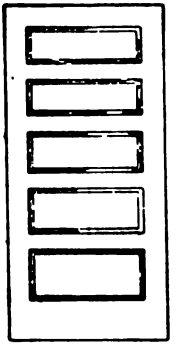

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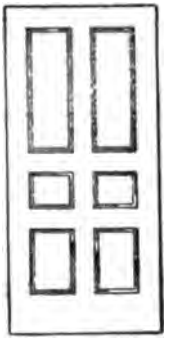

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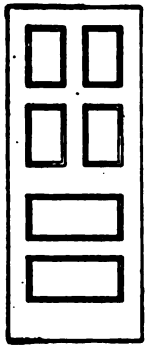
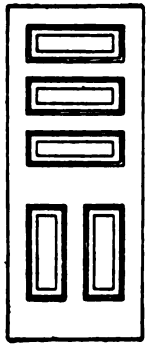


Fig. 215.



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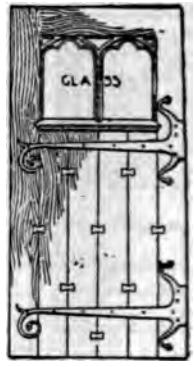

Fig. 217.

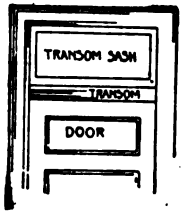

Fig. 218.

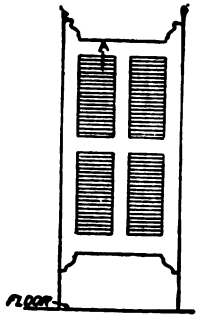

Fig. 219.

Fig. 220.

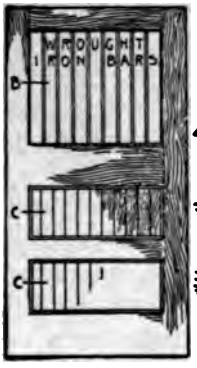

Fig. 221.

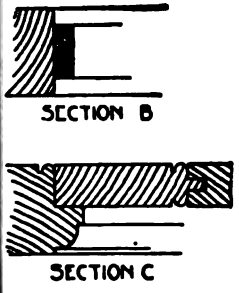

Fig. 222.

PART III.

MECHANICS OF CARPENTRY.

this part I intend to give the reader some prac-
instructions in "The Mechanics of Carpentry."
the methods of calculating the strength of trusses.
timbers for structural purposes. All the rules
have been taken from the best authorities, as
Rankine, Barlow, Hurst, Riley, Trautwine, Hatfield,
Mr. Nicholson and others. I have, in a few in-
stances, corrected and added to some of the propo-
sitions which I have found in practice, to be neces-

INTRODUCTION TO THE MECHANICS OF CARPENTRY.

It is well known that some members of a framed
must be made stronger than others. The
is due to the various other forces acting on a
from each other in magnitude and direc-
It is therefore necessary, therefore, to be able
the various forces acting, so that the mem-
may be made of the required strength without
of material. The general principles un
the measurement of forces may with advan
be explained briefly.

The Nature of Force. Force may be defined as that which moves, or tends to move, a body at rest, or which changes, or tends to change, the direction or rate of motion of a body already moving. A familiar example of force is met with in gravitation, whereby an object has a tendency to fall to the ground. In order to support it, an upward force equal to the weight of the object must be exerted. The phrase "equal force" implies that forces can be measured. In this country they are usually measured in terms of weights in lbs., cwts., etc. Any one who has seen a pulley, or lever, at work knows that the direction of application of a force can be changed. Evidently, then, forces can be represented graphically. Lines drawn to scale are employed and these can be arranged to exhibit at the same time both the magnitude and the direction of the forces. Thus, a weight of 10 lbs. acting vertically downwards can be represented by a vertical straight line 10 units in length. If the unit of length be $\frac{1}{8}''$, the line will measure ten times $\frac{1}{8}''=1\frac{1}{4}''$; whereas, if the unit of force be represented by a length of 1", the graphic representation of the force will be a vertical straight line 10" long.

Resultant of two or more Forces. (1) When two or more forces together act at a point in the same direction and in the same straight line, the **resultant** force is equal to the sum of the **components.**

Example. (a) If two 10 lb. weights attached to a cord are hung upon the same nail, the resultant weight acting upon the nail is $10+10=20$ lbs.

(2) If two equal forces together act at the same point in opposite directions, but in the same straight

line, they neutralize each other, and the forces are said to be in **equilibrium.**

Example. A spring balance carries a weight of 6 lbs. The index finger of the balance shows that the spring exerts an upward force equal to the downward force—the weight; and a state of equilibrium is obtained.

If the two unequal forces together act at the same point in opposite directions, but in the same straight line, the resultant force is equal to the difference between the forces, and is in the direction of the greater.

It is evident, then, that the directions of the forces, and therefore the angles they make with one another, must be considered in determining the forces acting at any given point.

If a flexible string be attached to a weight, and then passed over a frictionless pulley, there will be the same tension in every part of the string, irrespective of any change of direction caused by using the pulley.

To illustrate these facts clearly, suppose that two 7 lb. weights, connected by a cord, hang over a smooth peg as shown in Fig. 1. The total weight on the peg, neglecting the weight of the cord (which may thus be any length), is 14 lbs., the sum of the two weights.

Again, suppose three such pegs in a horizontal straight line, and the cord and weights to be passed over them as shown in Fig. 2. Evidently the weight on the central peg is nothing. Now, suppose the outside pegs to be lowered slightly, as shown by dotted lines in the figure; the central peg will now carry a small proportion of the weight, and the more the outside pegs are lowered, the more weight will be thrown

on the central peg, until, as shown in Fig. 1, it car all the weight, i. e., 14 lbs. Therefore the weight u the central peg varies according to the direction of forces acting on it—from nothing in Fig. 2 to 14 lbs Fig. 1.

The magnitude and direction of the resultant f acting upon the central peg, and upon each of the side pegs, can be determined by the parallelogra forces.

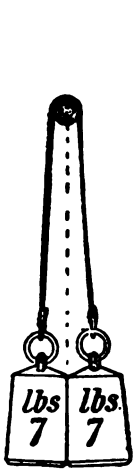

Fig. 1.

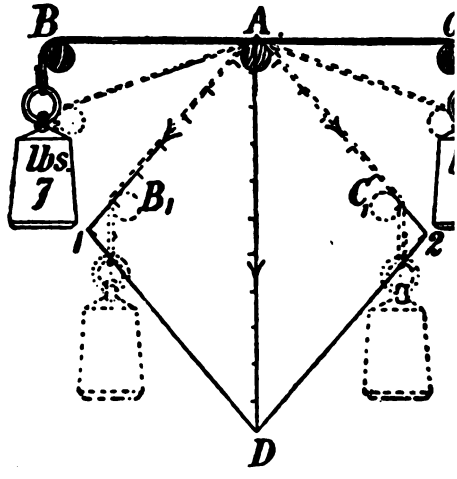

Fig. 2.

The Parallelogram of Forces.—If two forces a at a point be represented in magnitude and dire by the adjacent sides of a parallelogram, the resu of these two forces will be represented in magni and direction by that diagonal of the parallelo which passes through the point.

Example 1. The angle at A [illegible] over the pegs B_1. AC_1, shown [illegible] Fig. 2, is given. Determine [illegible] forces the stress on the peg A [illegible] acting through the point A. [illegible] effect to the forces AB_1, AC_1 [illegible]

Produce AB_1 and AC_1, and [illegible] units, measuring from A. Then [illegible] in magnitude and direction the [illegible] loads. Complete the parallelogram [illegible] parallel to A2, and 2D parallel to A1. [illegible] the diagonal AD, measured in the same [illegible] lines A1 and A2, represents the magnitude and direction of the resultant force—i. e., the stress on the peg A. The direction of the force will obviously be [illegible] force represented in magnitude and direction by AD would evidently counterbalance the forces AB and AC, and would therefore counterbalance A [illegible] gether. **Forces which balance each other are said to be in equilibrium.**

Example 2. Determine the magnitude and direction of the single force which will replace the forces exerted by the cord and weight on the peg B, Fig. 2.

Draw ab 7 units long (Fig. 3) parallel to the cord A1 in Fig. 2. From b draw bc 7 units long and parallel to the cord below the peg B. Complete the parallelogram by drawing dc and ad parallel to ab and bc respectively. Then the diagonal bd represents the magnitude of the required force, the direction of which is from b to d.

Example 3. Fig. 4 shows the application of parallelogram of forces to determine the resul force on the peg B.

In the above examples no allowance has been m for the weight of the cord or for the friction on pegs. It is assumed in each case that the forces acting at the point of intersection of the straight l produced.

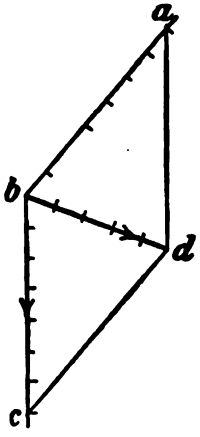

Fig. 3.

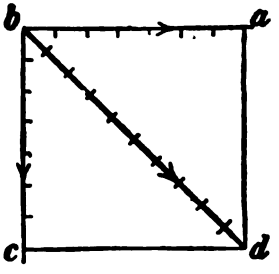

Fig. 4.

Example 4. Two forces of 10 and 6 lbs. respecti act from a point and in directions which are at r angles to each other. Determine the magnitude direction of the single force which can replace the forces.

Let the line A B (Fig. 5) represent in magnitu force of 10 lbs. acting at the point A in the dire indicated by the arrow, and A C a force of 6 lbs. a

at right angles to A B. Complete the parallelogram A C D B. Then the length of the diagonal A D represents the magnitude of the resultant force, and the direction in which it acts will be from the point A, as shown by the arrow.

It must be understood clearly that a resultant is a force which can take the place of, and will produce the same effect as, two or more forces. To maintain equilibrium, the resultant force must be counterbalanced by an equal force acting in the opposite direction. The force so acting is called the **equilibrant.**

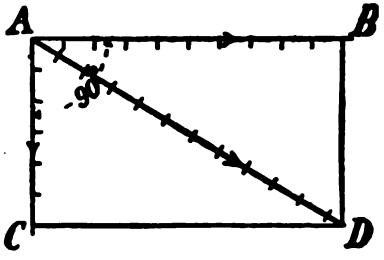

Fig. 5.

Example 5. Figs. 6 and 7 show the magnitude and direction of the resultant force when forces of 9 and 6 lbs. respectively act at angles of (a) 120°, (b) 45°.

The simple apparatus shown in Fig. 8 clearly illustrates the principle of the parallelogram of forces. On a vertical board are fixed two small pulleys by means of screws, so that they revolve with as little friction as possible. By making a three-way string, passing it over the two pulleys, and adding varying weights to

each of the three ends of the string, it can be demonstrated clearly how the three forces act. In Fig. 8 the weights are respectively 5, 6, and 4 lbs. By drawing the parallelogram A B D C, such that A B equals 5 units in length, and A C equals 4 units, the diagonal D A is found to measure 6 units, and to represent the magnitude of the middle weight. If other weights are attached to the ends of the strings, different results will, of course, be obtained.

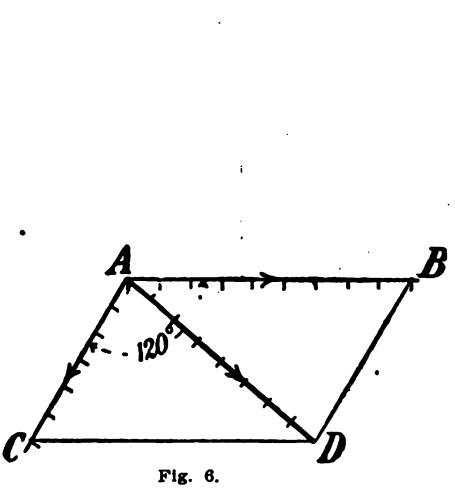

Fig. 6.

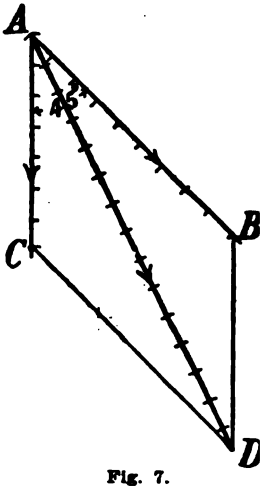

Fig. 7.

Triangle of Forces. The triangle of forces is used to determine the magnitude and direction of any three forces which balance each other. The rule may be stated as follows: **If three forces acting at a point are in equilibrium they can be represented in magnitude and direction by the three sides of a triangle taken in order.**

Example 1. The forces acting upon A (Fig. 8) are in equilibrium.

Since the length of the line A B=5 units, and the line B D is parallel and equal in length to A C=4 units, and the diagonal D A is in a line with the direction of the middle vertical weight and equal in length to 6 units; then the sides A B, B D, and D A of the triangle A B D represent both in magnitude and direction the forces acting at the point A.

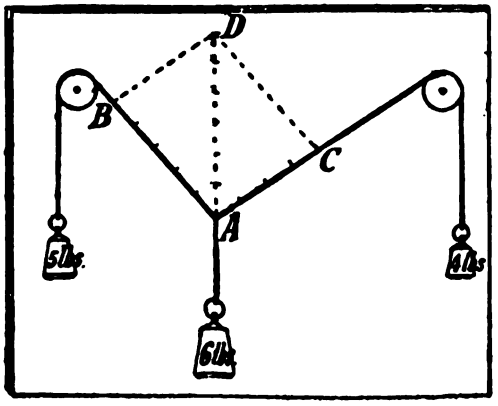

Fig. 8.

To save confusion it is usual, however, to draw a separate triangle to illustrate these forces. A somewhat different system of lettering also simplifies the consideration of the examples. This is known as **Bow's notation.** In it the two letters denoting a force are placed on each side of the line representing the force,

that is, in the spaces between such lines. Thus in Fig. 9 the three forces acting at the point o are referred to as A B, B C, C A respectively.

Example 2. Given the magnitude (9 lbs.) and the direction (indicated by the arrow) of A B, and the angles which the directions of the three forces make with each other, it is required to find the magnitude and direction of B C and C A when the forces are in equilibrium.

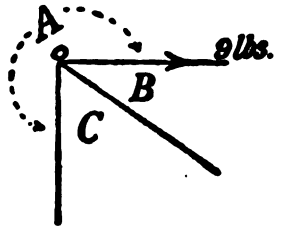

Fig. 9.

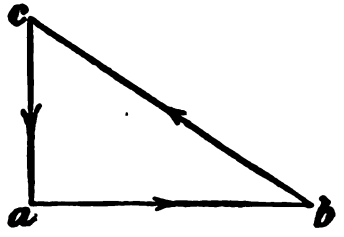

Fig. 10.

Draw the line a b (Fig. 10) parallel to the direction of action of the force A B, 9 units long, and in the direction shown by the arrow. From b draw b c parallel to B C until it meets a c drawn parallel to C A. Then the triangle a b c is the triangle of forces, and the direction of the forces B C and C A can be found by taking the sides of the triangle in order, viz., a to b, b to c, c to a; and these directions give also the directions of action of the forces represented by the lines parallel to a b, b c, and c a respectively. Thus A B acts from the joint o; B C acts towards o; and C A acts from o.

The following examples show the application of these principles to simple practical questions.

Example 3. A rope bears a tensile stress (pull) of 30 cwts. Find the magnitude of the stress in each of two other ropes which make an angle of 60° with each other, and together balance the stress in the first rope, supposing the second and third ropes are equally stressed.

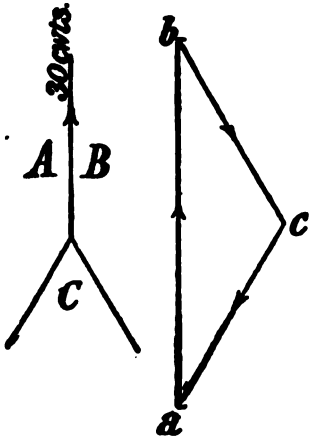

Fig. 11.

Fig. 11 shows the application of the triangle of forces to the solution of this question, the answer giving the stress in each rope as 17.32 cwts. By going round the sides of the triangle in order, it will be seen that the force in each of the three ropes acts from the joint.

Example 4. A buckling-chain is used to raise heavy blocks of stone. What is the amount of stress in the

links of the chain when raising a weight of on
the buckling-chain is:

(a) pulled tightly as in Fig. 12;

(b) placed loosely round the stone as in Fi

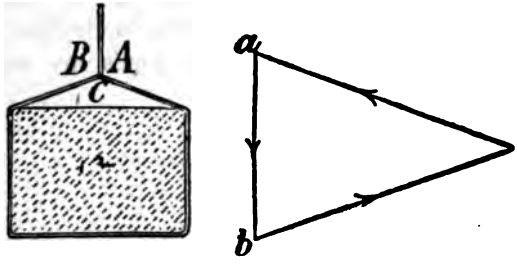

Fig. 12.

The correct solution of this question depend
the weight of the stone; (2) the angle betw
forces A C and B C.

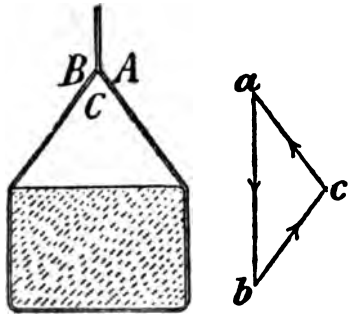

Fig. 13.

The application of the triangle of forces in e
(Figs. 12 and 13) shows that the stresses A C
are more than twice as great when the chain

as in Fig. 12 as they are with the arrangement in Fig. 13; or, the tighter the chain—i. e., the greater the angle between the forces B C and C A—the greater is the stress on the links.

Example 5. A triangular bracket fixed against a wall, as shown in Fig. 16, has a weight of 5 cwts. suspended from the outer end o. What is the nature and amount of stress in each of the members o A and o B?

Fig. 15 is the triangle of forces used to determine these stresses, and is drawn as follows: $1_1 2_1$ is drawn

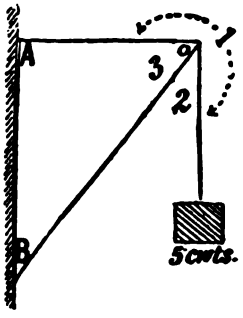

Fig. 14.

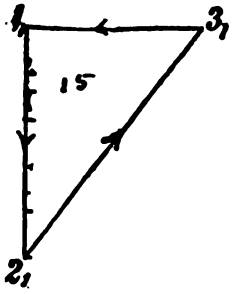

Fig. 15.

arallel to and represents the downward force (the eight of 5 cwts.) to scale. From 2_1 draw $2_1 3_1$ parallel o 2 3 in Fig. 14 until it meets $1_1 3_1$ drawn parallel to 3. Then the triangle $1_1 2_1 3_1$ represents the magnitude the forces.

By going round the triangle in order as shown by the rows, we find that 2 3 acts towards the joint o and therefore a compression stress or thrust, and 3 1 acts om the joint and is therefore a tension stress or pull.

Fig. 16 shows a somewhat modified design of t
gular wall-bracket, and Fig. 17 is the triangle of f
by which the stresses in the various members are a
tained.

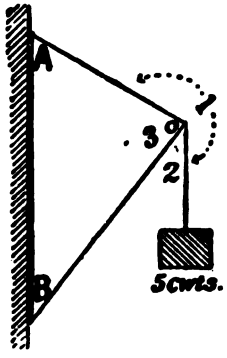

Fig. 16.

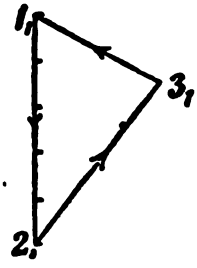

Fig. 17.

Example 6. What is the nature and amount of s
in each of the members A B and A C (Fig. 18) ca
by the weight of 10 cwts. acting as shown?

This example may be taken as typifying a sin
kind of roof-truss with the weight taking the pla
the ridge piece. Re-letter or figure the diagram acc
ing to Bow's notation. Draw the vertical line 1
equal in magnitude and direction to the weight
Complete the triangle by drawing lines parallel to
members A C and A B, from the points 2_1 and 3
spectively. These lines represent the amount of
along the members A C and A B. On taking the
of the triangle in order as shown by the arrows,

seen that $2_1 3_1$ act downwards; $3_1 1_1$ acts towards the joint A, as does also $1_1 2_1$; therefore each member is subject to a compression stress (thrust).

Fig. 19 shows another example of this kind with a much smaller angle between the forces.

Fig. 20 illustrates a still further example, where the two sides are of unequal inclination.

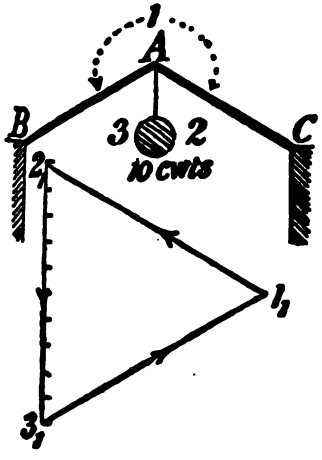

Fig. 18.

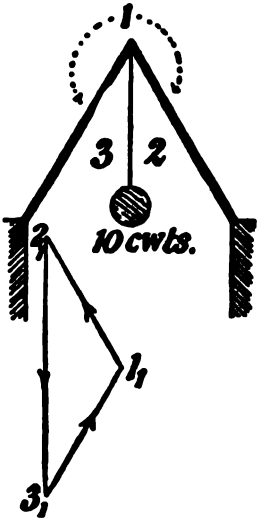

Fig. 19.

Polygon of Forces. The method of obtaining the sultant of any two forces acting at a point can be tended to three, four, or any number of forces.

Example. O A, O B, O C, O D, O E, (Fig. 21) repre- it the magnitude and direction of five forces acting

at the point O. Determine the magnitude and direc of the resultant force.

This problem can be solved either by an applica of the parallelogram of forces or by a direct cons tion.

(1) Determine by the parallelogram of forces, resultant O 1 of forces O A and O B (Fig. 22). S larly, determine the resultant O 2 of the forces O 1

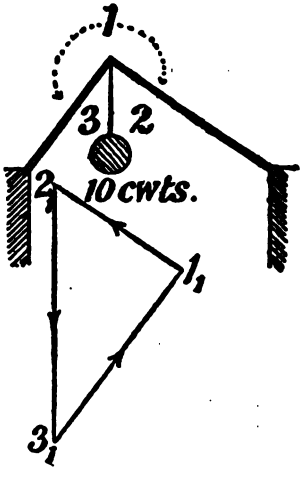

Fig. 20.

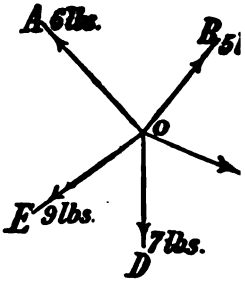

Fig. 21.

O C. Again, O 3 is the resultant of the forces O 2 a D; and finally O 4 is the resultant of O 3 and Therefore, O 4 is the resultant of all the original fo or, in other words, a single force equal in magn and direction to the force O 4 will have the same i at the point O as the five forces have when acti

gether. Since a force 4 O will balance O 4, a force represented in magnitude and direction by the line 4 O will, together with the five given forces, produce equilibrium at the point O.

(2) The same result may be obtained more simply as follows. Re-letter the forces as shown in italics (Fig. 22), and then, as in Fig. 23, draw a straight line a′b′

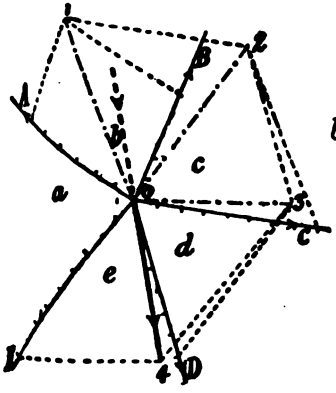

Fig. 22.

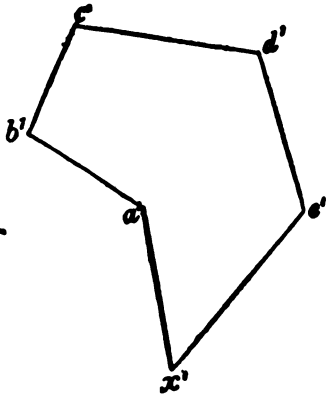

Fig. 23.

equal in magnitude and parallel to a b (Fig. 22). From b′ draw b′c′ equal and parallel to b c; continue the process, taking the forces in order. It will be found by drawing the closing line of the polygon, that is, by joining x′ to a′, that x′a′ gives the magnitude and the direction of the force required to produce equilibrium. Conversely, a′x′ is the resultant of all the original forces. By drawing the line 4 O through the point O (Fig. 22) and indexing it to scale, the required result-

ant—which corresponds with the one determined by the parallelogram of forces—is obtained. Its direction is indicated by the arrow.

Fig. 25 is the polygon of forces when two of the forces, b c and d e, act towards the joint (Fig. 24), the magnitude of all the forces being as in the previous example. In this case the equilibrant is determined, and is shown by the thick line in Figs. 24 and 25.

Fig. 24.

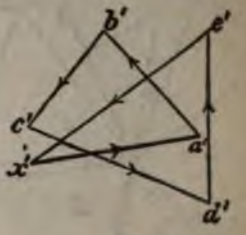

Fig. 25.

Figs. 21 and 25 should be compared carefully.

The **polygon of forces** may be stated as follows: **If two or more forces act at a point, then, if starting at any point a line be drawn to represent the magnitude and direction of the first force, and from the point thus obtained another line be drawn similarly to represent the second force, and so on until lines have been drawn representing each force,—the resultant of all these forces will be represented by a straight line drawn from the starting point to the point finally reached.**

Polygons, parallelograms, or triangles, of forces, when used to determine either the resultant or the equilibrant of stresses acting at a point, are called **reciprocal diagrams.**

Inclined Forces in one Plane but not acting through one Point. The foregoing examples deal only with forces which act at a single given point, and in these cases the resultant acts at the same point. When all the forces do not act at the same point, the magnitude and direction of the resultant is obtained as in previous examples, i. e., by drawing the reciprocal diagram; the line of action, however, still remains to be determined. To determine this line of action, it is necessary to draw what is known as the **funicular** or **link polygon.** The method is as follows:

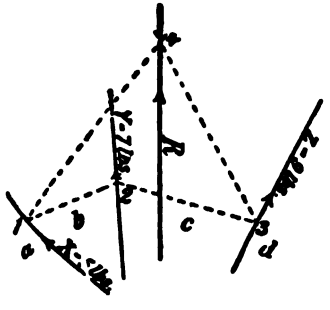

Fig. 26.

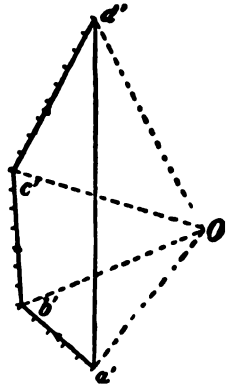

Fig. 27.

Example. Let X, Y, Z (Fig. 26) be three forces in the same plane and of the magnitude and direction shown. It is required to find the magnitude and the line of action of the resultant force.

Re-letter the forces a b c d according to Bow's notation and draw the reciprocal diagram a'b'c'd'; the line

a′d′ which closes the figure represents the magnitude of the resultant. To obtain the actual line of action of the resultant, take any point or pole O and join a′O, b′O, c′O, d′O. The figure thus obtained is called the **polar diagram**. The funicular polygon is now constructed by drawing—anywhere in the space b—a line 1 2 parallel to b′O and intersecting the forces X and Y at 1 and 2 respectively. From 2 draw 2 3 parallel to c′O, intersecting the force Z in 3. Through 1 draw 1 4 parallel to a′O, and through 3 draw 3 4 parallel to d′O. Through the point of intersection 4, draw a line R parallel to a′d′. R is the required line of action of the resultant of the three given forces, and its magnitude is represented by the length of a′d′.

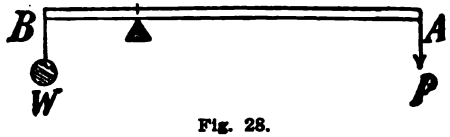

Fig. 28.

Parallel Forces. In addition to forces acting in the ways already explained, it is necessary to consider a few examples of **parallel** forces. (These must not be mistaken for those dealt with by the parallelogram of forces, as they are entirely different.)

In all the examples of parallel forces now to be considered, the forces will act vertically. As these can be shown easily both graphically and arithmetically, each example will be worked out by both methods.

The simplest examples of the equilibrium of parallel forces are found in the use of **levers**. The lever shown in Fig. 28 is a straight bar resting on a triangular

block, F, called a **fulcrum.** At the ends A and B of the lever, forces P and W respectively act vertically downwards. It is plain that forces P and W will tend to rotate the lever in opposite directions around the fixed point F. The tendency of either force to rotate the lever is called the **moment** of that force; it is measured by the product of the force into the perpendicular distance (called the **arm** of the force) of the fixed point from the line of action of the force. **When the two moments are equal the lever is in equilibrium.** The conditions of equilibrium therefore are:

$$P \times A\,F = W \times B\,F.$$

If A F be 6″, B F be 2″, and W=9 lbs., then P will require to be $\frac{9 \times 2}{6} = 3$ lbs.: the moment of each force being 18 inch-lbs.

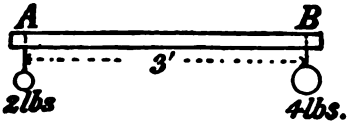

Fig. 29.

Since moments are always expressed in terms of the product of a force and a length, both these factors enter into every statement of the magnitude of a moment. If the distances be expressed in feet, and the forces in cwts., the moments will, of course, be expressed in ft.-cwts., and so on.

Example 1. A horizontal bar 3 ft. long has a weight of 2 lbs. at one end, and of 4 lbs. at the other end (Fig. 9). Find the point at which the bar must be sup-

ported so that it will rest horizontally. (Neglect the weight of the bar.)

Arithmetically.—Since the lever is in equilibrium, the total downward force of 6 lbs. is balanced by an upward force (reaction) of 6 lbs. at the unknown point of support, and the moment of the upward reaction, about any point, is equal to the sum of the moments of the downward forces about the same point. Consider moments about A:

Moment of weight at A, about A, $=2\times0$.
" " " " B " A, $=4\times AB$.
" reaction about A $=(2+4)\times AX$.
$\therefore\ 6\times AX=(2\times0)+(4\times AB)$;
$\therefore\ 6AX=0+(4\times3)$;
$\therefore\ AX=12/6=2$ feet

Graphically.—In the consideration of these forces graphically, the polygon of forces becomes a straight line. A polar diagram and a funicular polygon are required.

Fig. 30 shows the bars with the weights suspended. Letter the forces A B and B C. The polar diagram is drawn as follows: Draw to a suitable scale, a vertical line a c, 6 units long—equal to the sum of the weights. From any point O which may be at any convenient distance from a c, draw O a, O b, and O c. To construct the funicular polygon, draw, in the space B, 1 2 parallel to b o. From 1 draw 1 3 parallel to a O, and from 2 draw 2 3 parallel to O c, and produce it to intersect 1 3 in 3. Then the vertical line drawn through the point 3 will give the position of the fulcrum. If the distances from this point to the points of application of

the weights be measured, it will be found that they are in inverse proportion to the magnitudes of the

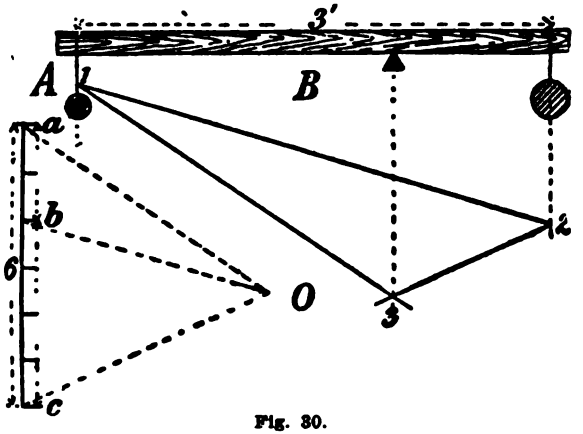

Fig. 30.

weights, and that the weight on the right hand side of the fulcrum, multiplied by its arm of leverage, will be equal to the weight on the left hand side, multiplied by the arm of leverage on that side—the arms being one and two feet respectively.

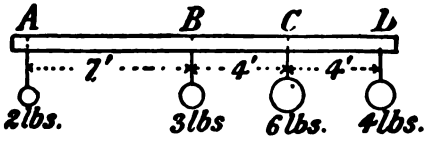

Fig. 31.

Example 2. Four weights of 2, 3, 6, and 4 lbs. respectively hang on a bar as shown in Fig. 31. Determine the point at which the bar must be supported to rest horizontally, the weight of the bar being neglected.

Arithmetically.—Let the required point of support be denoted by the letter X. When the bar is in equilibrium, the sum of the moments about A of the downward forces, must be equal to the moment, about A, of the upward reaction at the point of support.

$$\therefore \text{ the downward moments about A}$$
$$=(2\times 0)+(3\times 7)+(6\times 11)+(4\times 15)$$
$$= 0 + 21 + 66 + 60 = 147.$$

The moment about A of the upward reaction

$$=\text{Sum of all the weights}\times AX$$
$$=(2+3+6+4)\times AX=15AX;$$
$$\therefore \quad 15AX=147;$$
$$\therefore AX=147/15=9\ 4/5 \text{ feet.}$$

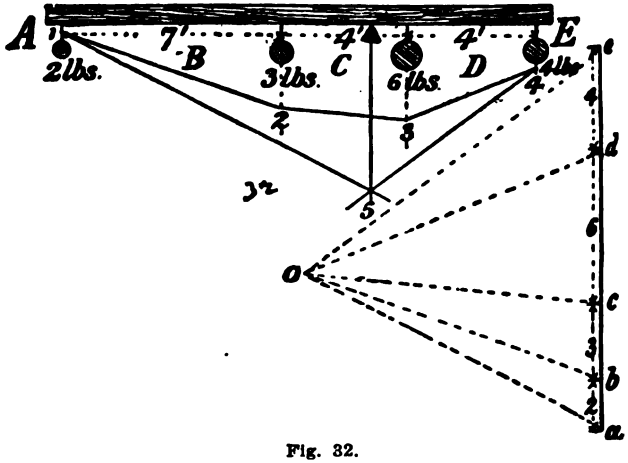

Fig. 32.

Graphically.—Draw the vertical line of loads ea representing to scale the sum of the weights as shown (Fig. 32). Construct the polar diagram by drawing

from any point O the lines e O, d O, c O, b O, and a O. To draw the funicular polygon, draw vertical lines under each weight, and—starting anywhere in the line of the first weight as at 1—draw in the space B a line 1 2 parallel to O b; in the space C draw 2 3 parallel to O c; in the space D draw 3 4 parallel to O d. Through 4 draw 4 5 parallel to e O and through 1 draw 1 5 parallel to O a. The vertical line drawn through the point 5, where these two lines meet, gives the position of the point of support.

Although the application of the lever as a tool or machine is an everyday occurrence with the workman in such appliances as the turning bar of the bench-vice and sash-cramp, the screw-driver, brace, pincers, claw-

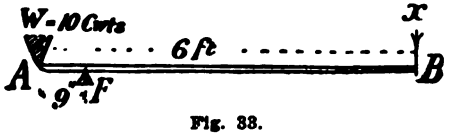

Fig. 33.

hammer, grindstone, treadle lathe, mortising-machine, etc., the detailed consideration of each of these cannot be entered into for want of space. The following examples involving the use of the crowbar will suffice further to illustrate the principles involved.

Example 1. What force must be exerted at one end of a crowbar 6 ft. long, to raise a weight of 10 cwts. at the other end: the bar resting on a fulcrum 9″ from the weight. (Neglect the weight of the crowbar.)

Let A B (Fig. 33) be the bar 6 ft. long, and F the fulcrum at 9″ from A. Consider moments in inch-lbs. about F. Let x be the required force.

Moment of 10 cwts. about F=9×10×112 inch-lbs.

Moment of x about F=BF×x=(72—9)×x=63×x inch-lbs.

$$\therefore x = \frac{9\times10\times112}{63} = 160 \text{ lbs.}$$

Example 2. A man weighing 140 lbs. is using a crowbar 5 ft. long. What must be the position of the fulcrum to enable him to balance a weight of 1260 lbs. at the other end?

Let A B be the length of the bar; F the position of the fulcrum; and x the length of the long arm in inches; then (60—x) is the length of the short arm in inches.

Taking moments about F,

$$140x = 1260(60 - x);$$

$$140x = 75600 - 1260x;$$

$$140x + 1260x = 75600;$$

$$1400x = 75600;$$

$$\therefore x = \frac{75600}{1400} = 54 \text{ in.} = 4' 6'' = \text{length of long arm.}$$

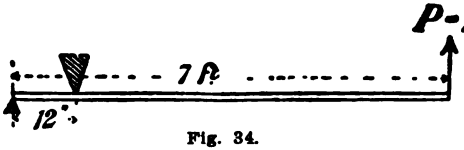

Fig. 34.

Example 3. A lever 7 ft. long is used as shown in Fig. 34. If a force of 200 lbs. is applied at P in the direction of the arrow, what weight, placed at a point 12″ from the fulcrum, can be raised?

Taking moments in ft.-lbs. about F,

$$W \times 1 = 200 \times 7;$$

$$\therefore \quad W = 1400 \text{ lbs.}$$

Loaded Beams. The determination of the proportion of the total weight carried by each support of a loaded beam—in other words, the upward reaction of each support which is necessary to maintain equilibrium—affords a good practical example of the theory of parallel forces.

Example 1. A beam rests upon supports placed 8 feet apart. A weight of 12 lbs. is placed on the beam at a distance of 2 ft. from the right-hand support. What proportion of the weight is carried by each of the supports, the weight of the beam being neglected?

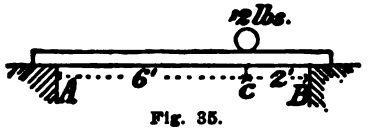

Fig. 35.

Arithmetically.—In this case (Fig. 35) the downward force (weight) of 12 lbs. must be balanced by upward forces (reactions) at the points of support, respectively equal to the pressure at these points, and together equal to 12 lbs.; and the moments of the upward forces about the point c must be equal.

$\therefore$ Reaction at A$\times$Ac=Reaction at B$\times$Bc,

i.e. Reaction at A:Reaction at B::Bc:Ac,

$$\text{or Reaction at A: } \frac{\text{Sum of reactions at A and B}}{} :: Bc : (Bc+Ac),$$

i.e. Reaction at A:12 lbs.::Bc:AB.

This may be expressed in general terms as follows:

$$\frac{\text{Pressure on one end caused by any load}}{\text{that load}} :: \frac{\text{Distance of that load from other end}}{\text{Length between supports.}}$$

therefore Pressure on A : 12 lbs. :: cB : AB;

$$\therefore \text{Pressure on A} = \frac{12 \times cB}{AB} = \frac{12 \times 2}{8} = 3 \text{ lbs.}$$

$$\text{Similarly, Pressure on B} = \frac{12 \times Ac}{AB} = \frac{12 \times 6}{6} = 9 \text{ lbs.}$$

Graphically.—Fig. 36 shows the beam and supports with the load in position. The polar diagram is drawn as follows: Draw a vertical line a b, representing the

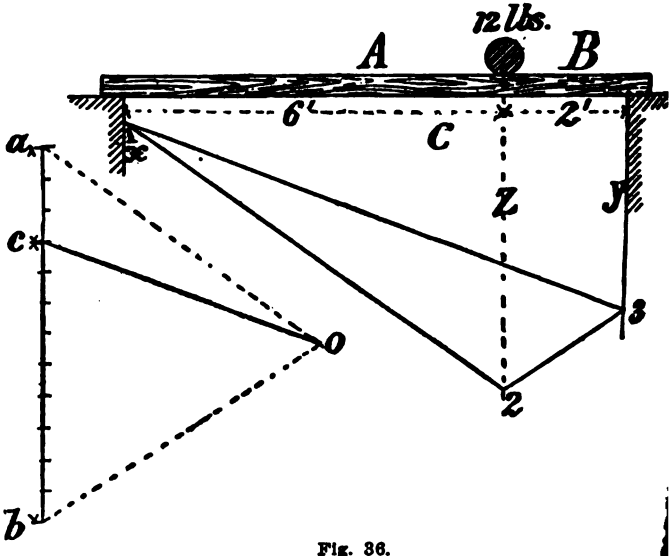

Fig. 36.

weight (12 lbs.) to a suitable scale. From any point O, which may be at any convenient distance from a b, draw the triangle O a b. Draw as in the figure a vertical line directly under the load, and one under each point of support, as Z, x, y. Letter the load A B. and

space between the supports C. These letters can w be used to denote the reaction at each point of support—i. e., the upward force required to maintain uilibrium—which is equal and opposite to the pres- re exerted on each support by the load. Anywhere x, as from 1, draw, in the space A, a line 1 2, parallel a 0; from 2, in the space B, draw 2 3 parallel to 0. Join 1 3, and through the pole O, draw O c parallel to 3 1. Then a c (on the vertical line of loads a b) represents to scale the pressure on the left-hand support, and c b to the same scale represents the pressure on the right-hand support.

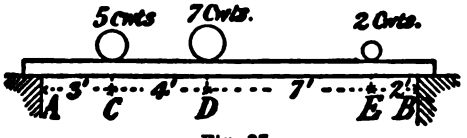

Fig. 37.

As the reaction at each end is equal in magnitude and opposite in direction to the pressure, a c gives the amount of the reaction A C, and b c gives the amount of the reaction B C; and the sum of the reactions—both acting upwards—is equal to the total weight (12 lbs.).

Example 2. A beam is loaded as shown in Fig. 37. Determine the reaction at each end, that is, the upward force required at each point of support to maintain equilibrium.

Arithmetically:

$$\text{Reaction at A due to weight at C} : \text{wt. at C} :: \text{CB} : \text{AB};$$

$$\therefore \text{Reaction at A due to weight at C} = \frac{\text{wt. at C} \times \text{CB}}{\text{AB}} = \frac{5 \times 13}{16}.$$

Similarly,

$$\text{Reaction at A due to weight at D} = \frac{\text{wt. at D} \times \text{DB}}{\text{AB}} = \frac{7 \times 9}{16}.$$

Also

$$\text{Reaction at A due to weight at E} = \frac{\text{wt. at E} \times \text{EB}}{\text{AB}} = \frac{2 \times 2}{16}.$$

The total reaction at A is equal to the sum of t partial reactions as shown above; or it may be obtain directly thus:

Total reaction at A

$$= \frac{(\text{wt. at C} \times \text{CB}) + (\text{wt. at D} \times \text{DB}) + (\text{wt. at E} \times \text{EB})}{\text{AB}}$$

$$= \frac{(5 \times 13) + (7 \times 9) + (2 \times 2)}{16} = \frac{132}{16} = 8\tfrac{1}{4} \text{ cwts.}$$

Similarly,

Total reaction at B

$$= \frac{(\text{wt. at C} \times \text{CA}) + (\text{wt. at D} \times \text{DA}) + (\text{wt. at E} \times \text{EA})}{\text{AB}}$$

$$= \frac{(5 \times 3) + (7 \times 7) + (2 \times 14)}{16} = \frac{92}{16} = 5\tfrac{3}{4} \text{ cwts.}$$

Graphically.—Construct the vertical line of loa representing to scale the sum of the weights as sho in Fig. 38. Fix the pole O, and draw the dotted li O a, O b, O c, O d. Letter the loads and draw a dott vertical line directly under each load and under ea support as shown. From any point in the first li draw in the space A, a line 1 2 parallel to a O; fr 2 draw 2 3 parallel to b O; from 3 draw 3 4 parallel c O; and in the space D, from 4 draw 4 5 parallel d O. Join 1 to 5, thus completing the funicular pol gon. By drawing a line parallel to 5 1—the closin line of this polygon—through pole O, and meeting th vertical line of loads at e, it is found that e a equa

the reaction E A, and e d equals the reaction E D; they are together equal to the sum of the weights in the beam.

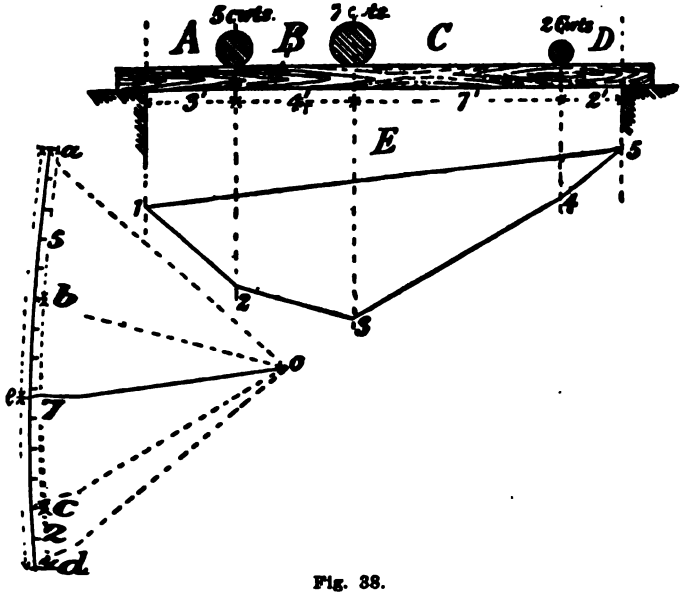

Fig. 38.

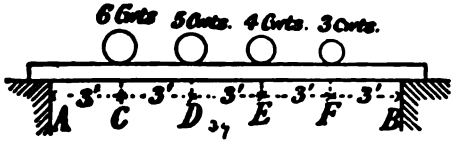

Fig. 39.

Example 3. A beam weighing 6 cwts. is loaded as shown in Fig. 39. Determine the reaction at each end necessary to produce equilibrium.

When the weight of a uniform beam is to b
ered, it may be taken as acting half-way bet
supports, and thus adding half its weight to e

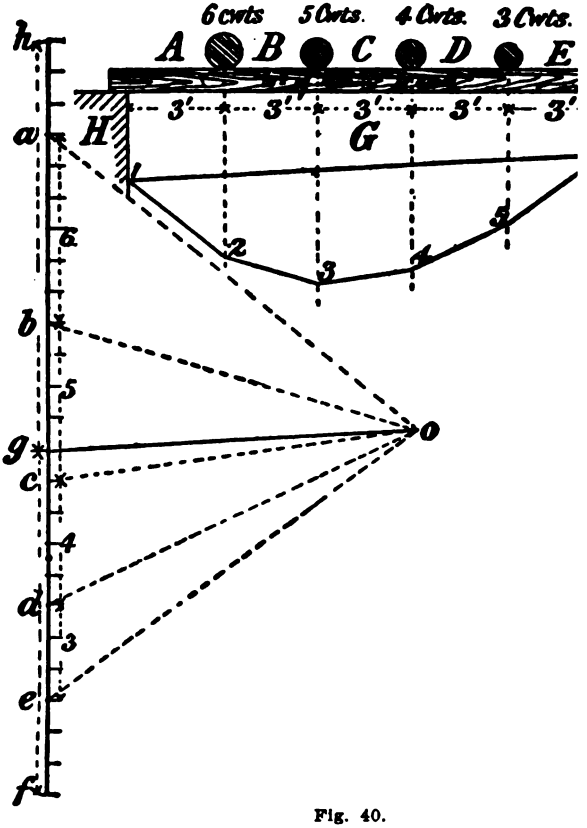

Fig. 40.

port. With this difference the method used is
previous example. Fig. 40 shows the graphi
tion.

Stress Diagrams for Roof Trusses.—Figs. 41 to 50 show an application of the foregoing graphic methods to the determination of stresses in roof trusses. Fig. 41 is a line diagram of a king-post truss loaded in the usual way. It must be noticed that the lettering is arranged so that every member is indicated by a letter on each side. It is first necessary to determine the amount of weight carried by each point of support. This example is simplified by the symmetrical loading, as one half the weight is carried by each point of support. When this is not the case, the proportion of the weight carried by each support must be determined first, by a consideration of parallel forces, as in earlier examples.

It is usual when determining the stresses of such a truss, to draw the stress diagram, shown in Fig. 46. This diagram is a combination of Figs. 42 to 45, which are only drawn as separate figures to assist in understanding the question more clearly.

Fig. 42 is the polygon of forces for the joint (1) at the foot of the principal rafter on the left. Four forces act at the point: A B downwards, B N the principal rafter, N G the tie beam, and the upward force. A G—the reaction at the point of support. Of these four forces the amounts of two, A B and A G, are known; it is required to determine the nature and amounts of the stress of B N and of N G when acting at the angles given.

Commencing Fig. 42 by drawing a b equal to A B, and a g equal to A G, the upward force. As these two forces are in the same straight line, and in opposite directions, their resultant is the line b g. From b

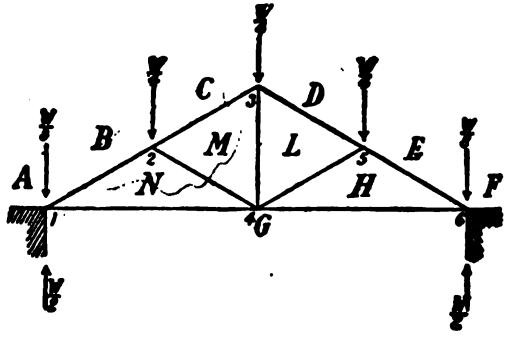

Fig. 41.

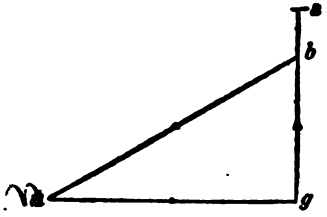

Fig. 42.

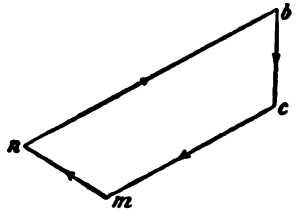

Fig. 43.

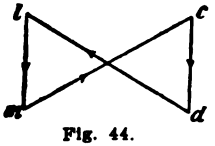

Fig. 44.

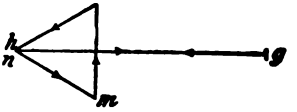

Fig. 45.

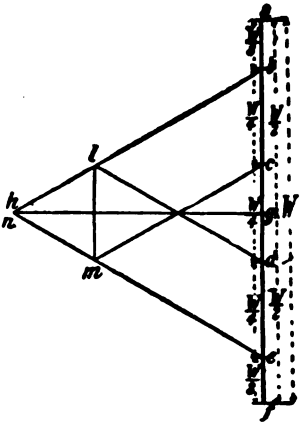

Fig. 46.

draw b n parallel to B N; and from g draw g n parallel to G N until b n and g n meet. Then b n g is the polygon (a triangle in this case) of forces acting at the point; and b n and n g represent the amount of stress in the principal rafter and tie-beam respectively.

The direction of the stress is found by taking the forces in order: thus, g b acts upwards; b n acts towards the joint, therefore this member is in compression; n g acts from the joint, which indicates that the tie-beam is in tension.

At joint (2), four forces act, namely, B C, B N, C M, and N M. The two known forces are B C acting downwards and B N towards the joint. For the magnitude of the stress on B N has already been found, and its direction of action at joint (2) is the opposite to its direction at joint (1). Fig. 43 shows the application of the polygon of forces to this joint. In it, b c and b n are drawn equal and parallel to B C and B N respectively; and, by drawing n m parallel to N M and c m parallel to C M, the stress diagram is obtained. This shows that the stress in C M, the upper part of the principal rafter, is much less than in B N, the lower part. By tracing the polygon, it is found that b c acts towards the joint, c m towards the joint (therefore C M is in compression), m n towards the joint (compression) and n b towards the joint (compression as in the previous figure).

At joint (3) there are four forces, i. e. C M, C D, D L, M L, acting as shown. Of these four forces the two C M and C D are known. Since the amount and nature of the stress in any member must be the same at any intermediate point between the joints, the stress

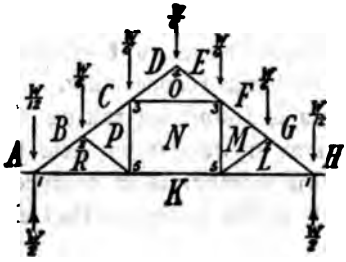

Fig. 47.

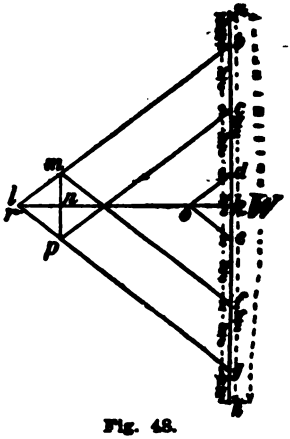

Fig. 48.

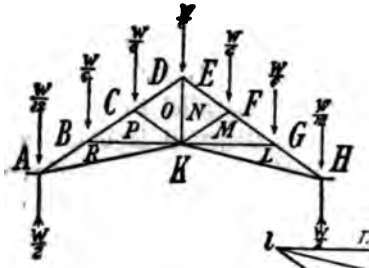

Fig. 49.

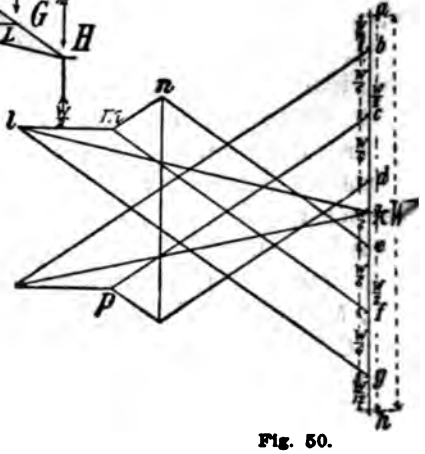

Fig. 50.

in C M acting upon joint (3) must be as determined by the diagram for joint (2). Fig. 44 is the stress diagram; c d is drawn parallel and equal to C D; c m parallel and equal to C M; m l and d l are drawn parallel to M L and L D respectively until they meet. Taking these forces in order, c d is towards the joint, D L towards the joint (compression), L M is from the joint (tension), and M C towards the joint (compression).

The tension stress in L M is caused by the struts M N and L H, which transfer part of the loads B C and D E respectively to the foot of the king-post. If no struts existed in this truss there would be no stress in M L.

Joint (4) has five forces acting, each one of which has already been determined, since the stress diagrams for one side of the truss are in this example applicable to each side. For example, the diagrams showing the stresses in the joints (1) and (2) are applicable to (6) and (5) respectively. An examination of Fig. 45 will show that g n is parallel and equal to G N; n m is parallel and equal to N M; l m is parallel and equal to L M; and l h being drawn parallel to L H meets m n in n, whilst h g is equal to n g. The diagram therefore shows the stress in each of the five members.

In Fig. 46, which is the complete stress diagram for the members of the truss, the lettering is identical with that in each of the separate Figs. 42 to 45, and will be easily understood from them.

Fig. 47 is a line diagram of a queen-post roof truss, and Fig. 48 is the stress diagram of this truss. Similarly, Figs. 49 and 50 are respectively the line diagram of and the stress diagram for, a composite roof truss,

sometimes named a German truss. The detailed explanation already given will enable the figures to be understood.

STRENGTH OF WOODEN BEAMS.

For the purpose of calculating the carrying capacity of wooden beams, it is necessary to notice the nature of the stresses to which they are subjected, as well as the manner in which they are loaded, and the arrangement of the load.

Stress and Strain. When a weight, or other force, acts upon a beam, it tends to change the shape and size of the beam. The force is technically called a **stress**, while the change in shape or size is called a **strain**. When a beam, or girder, supported at both

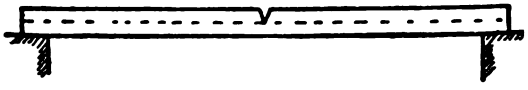

Fig. 51.

ends, is loaded, the upper part tends to shorten. The lower fibres, on the other hand, are in a state of tension, as they tend to stretch. The force acting on the upper fibres of such a beam is therefore a **compression stress**; that on the lower fibres is a **tension stress.**

The existence of these stresses may be made very apparent either by making a saw-cut across, or by actually cutting out a wedge-shaped piece from, the middle of a beam of wood for half its depth, as shown in Fig. 51. On resting the beam on two supports with the cut edge uppermost, and then loading it, it will be

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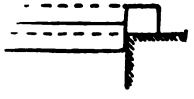


op of each other in the
pon supports at each end,
dle. The result will be that
wn in Fig. 52, and the boards
er. A shearing stress across
eam can be illustrated by tak-
some such soft material, resting
loading it. The result will be as

Methods of Arranging Beams. The nature amount of stress in the fibres of a loaded beam dep upon the way the beam is supported and on the rangement of the load. Thus a **cantilever** is a b with one end only secured upon a support, the o end overhanging. The load upon a cantilever ma a concentrated load at the outer end, as in Fig. 5 the load may be anywhere between the outer end

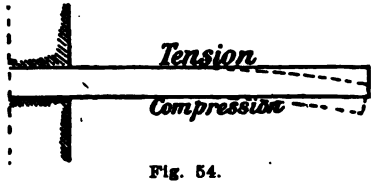


Fig. 54.

the supported end; a number of loads of var weights may be distributed over the length; the may be a uniformly distributed one extending ove length of the beam, or it may be a combination concentrated load and a distributed load. A cantil loaded in any of the ways just described has the f in the upper edge in a state of tension, those in lower half being in compression (Fig. 54).

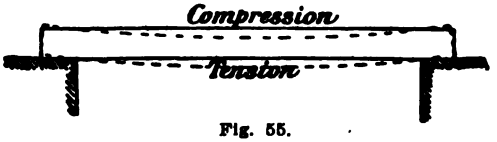


Fig. 55.

A beam supported at both ends may be loaded in of the ways described for the cantilever, with th sult that the stresses will be as shown in **Fig. 55**; the upper part will be in compression, and the l

in a state of tension. The stresses in the various of a loaded beam which has the **ends fixed** differ those of the beam which simply rests upon sup-

They are illustrated in Fig. 56, which shows or a distance of about one-fourth from each end ɜam takes the form of a cantilever, and has the in the upper half in a state of tension and the fibres in compression. The remainder of the has the upper fibres in compression and the part in tension. The neutral axis of all these is in the centre of the depth. If a long beam has ıediate supports as in Fig. 56, it may be regarded ng "fixed" at the points of intermediate support.

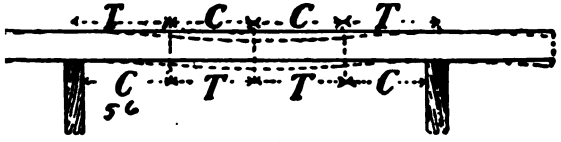


Fig. 56.

ding Moments. For the purpose of making com-ns of the relative strengths of loaded beams, a r consideration of the "moment of a force" is ary. Since the tendency to bending, to which a beam is subject at any point, depends upon the ıts of the stresses about that point, it is obvious ıe relative strengths of beams may be measured ms of moments. **The bending moment at any section is the algebraic sum of all the external acting on one side of the section.** Since it is at ınt where the greatest bending moment occurs ıe beam is subjected to the greatest stress, it fol-hat it is of some importance to be able to deter-

mine the bending moment of beams loaded under different conditions. The bending moment—like other moments—must always be expressed in terms of a length and a force.

Example 1. A cantilever carries a load of 6 tons at its outer end, which is 5 ft. from the supporting wall. Determine the maximum bending moment, and also the bending moment at 2 ft. from the wall.

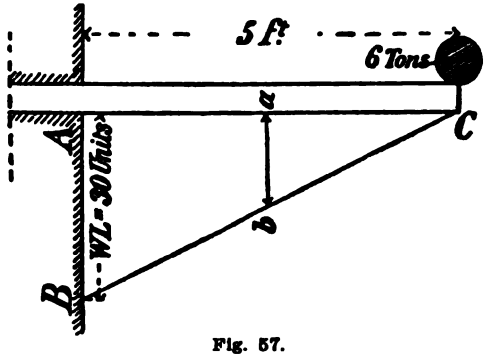


Fig. 57.

The greatest tendency to bending will be at the point of support, i. e. at a distance of 5 ft. from the load.

∴ Maximum bending moment=5×6=30 ft.-tons.

Bending moment at 2 ft. from the wall (i. e. 3 ft. from the load) =3×6=18 ft.-tons.

The bending moment at any distance from the load may be determined graphically by drawing, as in Fig. 57, a vertical line A B 30 units long (respecting the maximum bending moment) under the point of support A (i. e. the point where the bending moment is a maximum), and joining B C. Then the bending moment at the point a will be represented by the length of a b drawn parallel to A B.

Example 2. A cantilever projects 4 ft. and carries a uniformly distributed load of 8 cwts. along the upper edge. Determine the maximum bending moment, and also draw a diagram from which the bending moment at any section along the length of the cantilever may be determined.

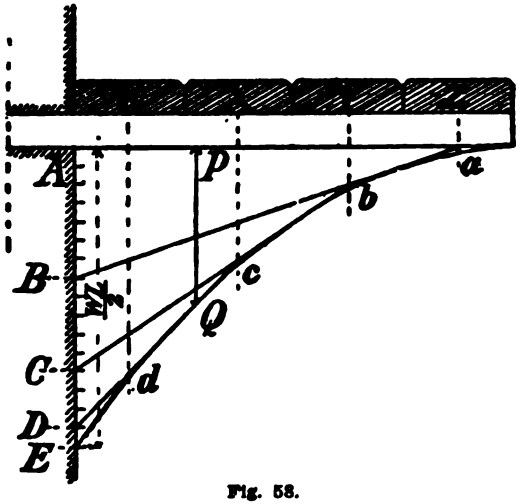


Fig. 58.

A load arranged as shown in Fig. 58 is equivalent to a concentrated load of 8 cwts. acting in the middle of the length, i. e. 2 ft. from the point of support. The maximum bending moment will therefore be

$$8 \times 2 = 16 \text{ ft.-cwts.}$$

Fig. 58 is the diagram from which the bending moment at any section may be determined. The load is supposed divided into 4 equal parts, and the bending moment due to each part is drawn to scale on the verti-

cal line A E. The weight of Z acts at 3′ 6″ and the maximum bending moment due to Z= 7 ft.-cwts. Draw A B 7 units long. Simil maximum bending moment due to Y=2×2. cwts., and is represented by B C; maximum

Fig. 59.

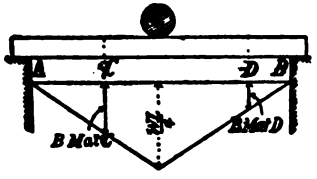
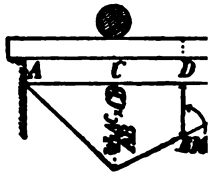


Fig. 60



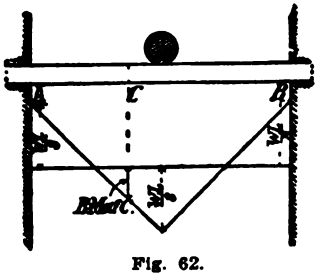


Fig. 62.

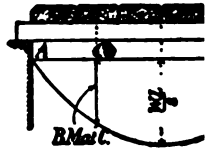


Fig. 63.

moment due to X=2×1.5=3 ft.-cwts., repres C D; maximum bending moment due to W=: ft.-cwt., represented by D E. The maximum moment due to the total load is therefore 7- =16 ft.-cwts., and is represented by A E. Dr tical line through the centre of each part of and complete the triangles A a B, B b C, C c Draw an even curve touching the lines E d, B a. This curve is a parabola. The bending

at any section P is represented by the length of the vertical line P Q cutting the parabola at Q.

The following formulæ are used for determining the relative bending moments (and therefore the relative strengths required) of beams loaded in various ways. In each case L=the length of the beam and W=the weight of the load.

	Maximum Bending Moment.	Relative Strength.
Cantilever fixed at one end and loaded at the other end (Fig. 57),	WL	1
Cantilever fixed at one end and loaded with uniformly distributed load,	$\frac{WL}{2}$	2
Beam supported at both ends and loaded with a central load (Fig. 59),	$\frac{WL}{4}$	4
Beam supported at both ends and loaded with a uniformly distributed load (Fig. 65),	$\frac{WL}{8}$	8
Beam fixed at both ends and loaded with a central load (Fig. 62),	$\frac{WL}{8}$	8
Beam fixed at both ends and loaded with a uniformly distributed load,	$\frac{WL}{12}$	12

Figs. 60 to 63 show beams loaded in various ways, and serve to illustrate the method of determining graphically the bending moment at any section of the beam.

It will be noticed that the maximum bending moment of a beam supported at each end is in each case in the line of the load, and with a central or an evenly distributed load is at the middle of the length of the beam.

Calculation of the Transverse Strength of Wooden Beams. Other things being equal, the strength of a

rectangular wooden beam is directly proporti
the breadth in inches multiplied by the squar
depth in inches, and inversely proportional
length in feet. Of course the nature of the
is also an important factor, since timber, eve
same kind, varies in strength to a considerable
Each beam therefore has what is called a natu
stant, which must be considered in the calcul
its carrying capacity. To obtain this consta
usual to take a bar of similar wood, 1 inch s
section, and long enough to allow of its being
on supports 1 foot apart. The constant is the
of the central load, which is just sufficient t
the bar. The constant may be expressed in lbs
tons, etc., and the carrying capacity will alwa
the same terms. The following constants (i
may be adopted for the purposes of calculatio
ash and pitch pine, 5; red deal, red pine and b
white and yellow pine, 3.

Another important consideration is the rati
the breaking load of a beam bears to the "saf
This ratio is called the **factor of safety,** and i
depends upon whether the load is a live—a co
moving—load, or a dead (i. e., a stationary) lo
factor of safety for a dead load is usually tak
which means that the safe load upon a beam
exceed one-fifth of the breaking load; the f
safety for a live load is often taken at 10.

For beams supported at both ends the

$W = \frac{bd^2c}{L}$ may be used for the purposes of

tion when:

W=breaking weight or maximum carrying capacity of a centrally loaded beam, expressed in the same terms as the constant,
b=breadth of the beam in inches,
d=depth of the beam in inches,
L=length of the beam in feet,
c=the constant, found by experiment as described above, and expressed in terms of lbs. or cwts.

To illustrate the above formula, take two pieces of the same kind of wood say 7 ft. long, 6 in. wide and 2 in. thick. Place one of these pieces flat, and the other on one edge, the distance between the supports in each case being 6 ft. As the constant is the same in both (say 5 cwts.), the carrying capacity of each will be expressed by the formula $W=\frac{bd^2c}{L}$;

for the flat beam, $W=\frac{6\times2\times2\times5}{6}=20$,

for the one on edge, $W=\frac{2\times6\times6\times5}{6}60$;

and the relative strengths will be as 20:60 or as 1:3.

When it is necessary to find other terms than W, the equation $W=\frac{bd^2c}{L}$ may be expressed as follows:

$$L=\frac{bd^2c}{W};\quad b=\frac{WL}{d^2c};\quad d^2=\frac{WL}{bc};\quad d=\sqrt{\frac{WL}{bc}};\quad c=\frac{WL}{bd^2}$$

The value of W for a **distributed load** is twice that for a concentrated load, i. e., $W=\frac{2bd^2c}{L}$. When the ends are fixed the carrying capacity is increased by about one-half.

For safe central loads the formula $W=\frac{bd^2c}{LF}$ is used: F being the factor of safety.

Example 1. Find the maximum carrying capacity of a centrally loaded wooden beam of pitch pine, 13 ft. long (12 ft. between the supports), 10 in. wide, and 6 in. thick, (1) when placed on edge; (2) when placed flat. Assume a constant of 5 cwts.

Applying the formula

$$W=\frac{bd^2c}{L}, \quad (1)\ W=\frac{6\times10\times10\times5}{12}=250 \text{ cwts. when on edge.}$$

$$(2)\ W=\frac{10\times6\times6\times5}{12}=150 \text{ cwts. when placed flat.}$$

Example 2. What would be the maximum safe load to which the beam in Ex. 1 may be subjected (1) as a central load; (2) as a uniformly distributed load?

Formula for safe central load using a factor of safety of 5, is

$$\text{Safe central load}=\frac{bd^2c}{LF}$$

$$=\frac{6\times10\times10\times5}{12\times5}=50 \text{ cwts. for beam on edge,}$$

or $$=\frac{10\times6\times6\times5}{12\times5}=30 \text{ cwts. for beam placed flat.}$$

Formula for safe central load using a factor of safety using factor of safety of 5, is

$$\text{Safe distributed load}=\frac{2bd^2c}{LF}$$

$$=\frac{2\times6\times10\times10\times5}{12\times5}=100 \text{ cwts. for beam on edge,}$$

or $$=\frac{2\times10\times6\times6\times5}{12\times5}=60 \text{ cwts. for beam placed flat.}$$

Example 3. Find the breadth of a beam of oak resting upon supports 18 feet apart, the beam being 12 in. deep, to carry safely a uniformly distributed load of 5 tons. Constant 5 cwts.

$$\text{Safe distributed load, } W = \frac{2bd^2c}{LF};$$

$$\therefore b = \frac{WLF}{2d^2c} = \frac{(5\times20)\times18\times5}{2\times12\times12\times5} = \frac{25}{4} = 6\tfrac{1}{4} \text{ inches.}$$

Example 4. A beam of red or yellow pine 20 ft. long (between supports), and 10 in. broad has to carry safely (1) as a central load, (2) a distributed load of 4 tons. What must be the minimum depth of the beam in each case? (Constant 4 cwts.)

$$\text{With a central load } d^2 = \frac{WLF}{bc};$$

$$\therefore d = \sqrt{\frac{WLF}{bc}} = \sqrt{\frac{80\times20\times5}{10\times4}} = \sqrt{200} = 14.14 \text{ inches.}$$

With a distributed load

$$d = \sqrt{\frac{WLF}{2bc}} = \sqrt{\frac{80\times20\times5}{2\times10\times4}} = \sqrt{100} = 10 \text{ inches.}$$

Example 5. What size of beam is required to carry safely a central load of 35 cwts. over a 10 ft. span; the depth and breadth of the beam being in the proportion of 7 :5? (Constant 5 cwts.)

$$b = \tfrac{5}{7}d;$$

$$d^2b = \frac{WLF}{c}$$

$$\text{i.e. } d^2\cdot\frac{5}{7}d = \frac{WLF}{c}$$

$$\frac{5d^3}{7}=\frac{WLF}{c}$$

$$d^3=\frac{7WLF}{5c}=\frac{7\times35\times10\times5}{5\times5}=400.$$

$$d=\sqrt[3]{490}=7.88''=\text{nearly } 8''.$$

$$\therefore b=\frac{5\times7.88}{7}=5.6 \text{ inches.}$$

The strength of flitched girders may be calculated by considering the wooden beam and iron flitch separately. The thickness of the flitch is usually about 1-12 that of the wooden beam. The constant for wrought iron is 25 cwts.

Deflection. In arranging beams it is necessary to consider not merely the strength of the beam, but also its liability or otherwise to be bent out of shape—or deflected—by the load placed upon it; since a beam which is overloaded and bent to a large extent has the fibres strained and therefore permanently weakened. The resistance which a beam offers to deflection is called its **stiffness**. It should be noticed that the "strongest" beam is not necessarily the "stiffest," nor the stiffest beam the strongest.

It is of importance to be able to determine the cross-sections of the strongest and the stiffest beams respectively which can be cut from a given log.

Suppose the log is of circular cross-section.

(a) To find the cross-section of the strongest beam. —Draw a diameter A B(Fig. 64) and divide it into 3 equal parts at 1 and 2. From 1 and 2 draw perpendiculars to AB cutting the circumference at C and D respectively. Join ACBD. The rectangle ACBD is the section required.

(b) To find the cross-section of the stiffest beam.—Divide the diameter AB (Fig. 65) into 4 equal parts at 1, 2, 3, and draw 1C and 3D perpendicular to AB, and cutting the circumference in C and D respectively. The rectangle ACBD is the section required.

Since the strength of a beam is proportioned to $\frac{bd^2}{L}$, **and the value of this fraction increases as d increases when bd (i. e., the sectional area) remains**

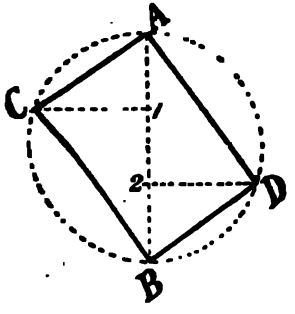


Fig. 64.

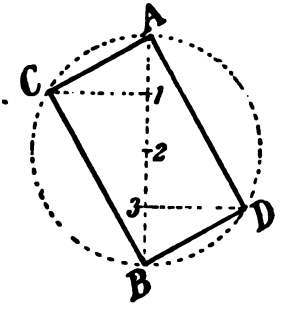


Fig. 65.

constant, the strongest beam of any given sectional area would be that of greatest depth if the tendency to buckling could be avoided. In the case of floor joists the ratio of depth to breadth is often as 3:1 or even 4:1, and the tendency to buckling is overcome by strutting. The strongest beam is that which has the depth to the breadth as 7:5.

Pulleys. It is necessary to consider one or two s
ple arrangements by which pulleys are used for h
ing purposes. In the following examples the fric
will for the sake of simplicity be neglected, altho
in practice it must be taken into account. Fig.
illustrates the simplest application of the pulley. I

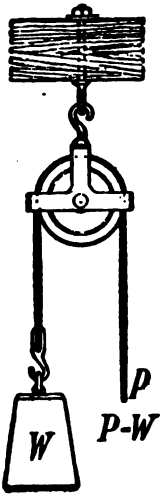


Fig. 66.

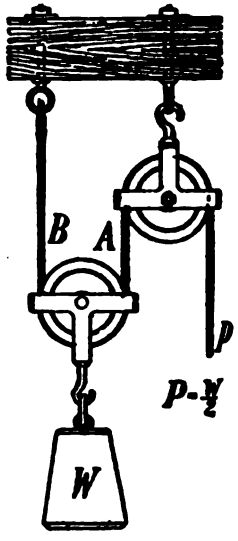


Fig. 67.

plain that when the forces acting on the pulley are i
equilibrium they are equal, and the only advantag
gained is in the change of direction of the force r
quired to balance W. Therefore in this example P=W

In Fig. 67 the force balancing P is the tension o
the cord A, which is equal to that of B. The sum o

these two equal tensions is plainly equal to the weight W. Therefore $P=\frac{W}{2}$, and the mechanical advantage is 2.

Figs. 68 and 69 are illustrations of a two- and three-sheaved pulley block respectively. By arranging pulleys side by side in this manner, and using a combination of two similar blocks as in Fig. 70 a mechanical advantage equal to the number of pulleys around which the rope passes is obtained. In other words, the

Fig. 68.

Fig. 69.

power required is equal to the weight raised divided by the number of pulleys around which the rope passes. Thus with 3 pulleys in each block there will be six cords, and the power required to balance a weight of 18 cwts. will be $18 \div 6 = 3$ cwts., plus the force required to overcome friction.

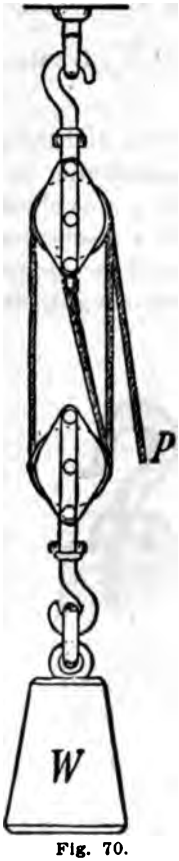


Fig. 70.

Specific Gravity. The s gravity, or relative density, body is the ratio of the wei that body to the weight of an volume of water. Thus a bl wood weighing 40 lbs. per cub has a specific gravity of $\frac{40}{62.5}$ (since a cubic foot of water v 62.5 lbs.).

When a body floats in wate is therefore in equilibrium weight of the body is balanc an equal upward reaction weight of the water displaced equal to the total weight c floating body.

Example. A block of wood x9″, floats in water with its surface 2.5″ above the surface water. Find its specific gravit $\frac{6\frac{1}{2}}{9} = \frac{13}{18}$ of the block is subm

By definition, the specific g of the wood is the ratio weight of any portion of the to the weight of an equal volume of water. C the part of the block below the surface of the

$$\text{Specific gravity} = \frac{\text{Weight of submerged part of v}}{\text{Weight of displaced water}}$$

$$= \frac{\text{Weight of submerged part of v}}{\text{Weight of whole block}}$$

$$= \frac{\text{Volume of submerged part of wood}}{\text{Volume of whole block}}$$

$$= \frac{13}{18} = 0.72.$$

In addition to the foregoing I have thought it essential to add the following special notes which are the results of actual experiments, and which will, I am sure, appeal to the American workmen, especially those who are located in the West, where timber is yet often employed in heavy structures.

STRENGTH OF TIMBER.

Proposition I. The strengths of the different pieces of timber, each of the same length and thickness, are in proportion to the square of the depth; but if the thickness and depth are both to be considered, then the strength will be in proportion to the square of the depth, multiplied into the thickness; and if all the three dimensions are taken jointly, then the weights that will break each will be in proportion to the square of the depth multiplied into the thickness, and divided by the length; this is proved by the doctrine of mechanics. Hence a true rule will appear for proportioning the strength of timbers to one another.

Rule. Multiply the square of the depth of each piece of timber into the thickness; and each product being divided by the respective lengths, will give the proportional strength of each.

Example. Suppose three pieces of timber, of the following dimensions:

The first, 6 inches deep, 3 inches thick, and 12 feet long.

The second, 5 inches deep, 4 inches thick, and 8 feet long.

The third, 9 inches deep, 8 inches thick, and 15 feet long. The comparative weight that will break each piece is required.

Ans. 9, 12½, and 43 1-5.

Therefore the weights that will break each are nearly in proportion to the numbers 9, 12, and 43 leaving out the fractions, in which you will observe that the number 43 is almost 5 times the number 9; therefore the third piece of timber will almost bear 5 times as much weight as the first, and the second piece nearly once and a third the weight of the first piece; because the number 12 is once and a third greater than the number 9.

The timber is supposed to be everywhere of the same texture, otherwise these calculations cannot hold true.

Proposition II. Give the length, breadth, and depth of a piece of timber; to find the depth of another piece whose length and breadth are given, so that it shall bear the same weight as the first piece, or any number of times more.

Rule. Multiply the square of the depth of the first piece into its breadth, and divide that product by its length: multiply the quotient by the number of times as you would have the other piece to carry more weight than the first, and multiply that by the length of the last piece, and divide it by its width; out of this last quotient extract the square root, which is the depth required.

Example I. Suppose a piece of timber 12 feet long, 6 inches deep, 4 inches thick; another piece 20 feet

long, 5 inches thick; required its depth, so that it shall bear twice the weight of the first piece.

Ans. 9.8 inches, nearly.

Example II. Suppose a piece of timber 14 feet long, 8 inches deep, 3 inches thick; required the depth of another piece 18 feet long, 4 inches thick, so that the last piece shall bear five times as much weight as the first.

Ans. 17.5 inches, nearly.

Note.—As the length of both pieces of timber is divisible by the number 2, therefore half the length of each is used instead of the whole; the answer will be the same.

Proposition III. Given the length, breadth, and depth, of a piece of timber; to find the breadth of another piece whose length and depth is given, so that the last piece shall bear the same weight as the first piece, or any number of times more.

Rule. Multiply the square of the depth of the first piece into its thickness; that divided by its length, multiply the quotient by the number of times as you would have the last piece bear more than the first; that being multiplied by the length of the last piece, and divided by the square of its depth, this quotient will be the breadth required.

Example I. Given a piece of timber 12 feet long, inches deep, 4 inches thick; and another piece 16 feet ng, 8 inches deep; required the thickness, so that it all bear twice as much weight as the first piece.

Ans. 6 inches.

Example II. Given a piece of timber 12 feet long, inches deep, 3 inches thick; and another piece 14

feet long, 6 inches deep; required the thickness, so that the last piece may bear four times as much weight as the first piece.

Ans. 9.722 inches.

Proposition IV. If the stress does not lie in the middle of the timber, but nearer to one end than the other, the strength in the middle will be to the strength in any other part of the timber, as 1 divided by the square of half the length is to 1 divided by the rectangle of the two segments, which are parted by the weight.

Example I. Suppose a piece of timber 20 feet long, the depth and width is immaterial; suppose the stress or weight to lie five feet distant from one of its ends, consequently from the other end 15 feet, then the above portion will be $\frac{1}{10 \times 10} = \frac{1}{100} : \frac{1}{5 \times 15} = \frac{1}{75}$ as the strength at five feet from the end is to the strength at the middle, or ten feet, or as $\frac{100}{100} = 1 : \frac{100}{75} = 1\frac{1}{3}$.

Hence it appears that a piece of timber 20 feet long is one-third stronger at 5 feet distance for the bearing, than it is in the middle, which is 10 feet, when cut in the above proportion.

Example II. Suppose a piece of timber 30 feet long; let the weight be applied 4 feet distant from one end or more properly from the place where it takes its bearing, then from the other end it will be 26 feet and the middle is 15 feet; then, $\frac{1}{15 \times 15} = \frac{1}{225} : \frac{1}{4 \times 26} = \frac{1}{104}$ or as $\frac{225}{225} = 1 : \frac{225}{104} = 2\frac{17}{104}$ or nearly $2\frac{1}{6}$.

Hence it appears that a piece of timber 30 feet long will bear double the weight, and one-sixth more, at four feet distance from one end, than it will do in the middle, which is 15 feet distant.

Example III. Allowing that 266 pounds will break a beam 26 inches long, requireth the weight that will break the same beam when it lies at 5 inches from either end; then the distance to the other end is 21 inches; $21 \times 5 = 105$, the half of 26 inches is 13; $13 \times 13 = 169$; therefore the strength at the middle of the piece is to the strength at 5 inches from the end, as $\frac{169}{169} : \frac{169}{105}$ or as $1 : \frac{169}{105}$ the proportion is stated thus : 1 : $\frac{169}{105}$ :: 266 : 428+, Ans.

From this calculation it appears, that rather more than 428 pounds will break the beam at 5 inches distance from one of its ends, if 266 pounds will break the same beam in the middle.

By similar propositions the scantlings of any timber may be computed, so that they shall sustain any given weight; for if the weight one piece will sustain be known, with its dimensions, the weight that another piece will sustain, of any given dimensions, may also be computed. The reader must observe, that although the foregoing rules are mathematically true, yet it is impossible to account for knots, cross-grained wood, &c., such pieces being not so strong as those which are straight in the grain; and if care is not taken in choosing the timber for a building, so that the grain of the timbers run nearly equal to one another, all rules which can be laid down will be baffled, and con-

sequently all rules for just proportion will be useless in respect to its strength. It will be impossible, however, to estimate the strength of timber fit for any building, or to have any true knowledge of its proportions, without some rule; as without a rule everything must be done by mere conjecture.

Timber is much weakened by its own weight, except it stands perpendicular, which will be shown in the following problems; if a mortice is to be cut in the side of a piece of timber, it will be much less weakened when cut near the top, than it will be if cut at the bottom, provided the tenon is driven hard in to fill up the mortice.

The bending of timber will be nearly in proportion to the weight that is laid on it; no beam ought to be trusted for any long time with above one-third or one-fourth part of the weight it will absolutely carry: for experiment proves, that a far less weight will break a piece of timber when hung to it for any considerable time, than what is sufficient to break it when first applied.

Problem I. Having the length and weight of a beam that can just support a given weight, to find the length of another beam of the same scantling that shall just break with its own weight.

Let l=the length of the first beam,
L=the length of the second;
a=the weight of the first beam,
w=the additional weight that will break it.

And because the weights that will break beams of the same scantling are reciprocally as their lengths,

therefore $\frac{1}{l} : \frac{1}{L} : : w+\frac{a}{2} : \frac{w+\frac{a}{2}}{L}l = W =$ the weight that will break the greater beam; because $w+\frac{a}{2}$ is the whole weight that will break the lesser beam.

But the weights of beams of the same scantling are to one another as their lengths:

Whence, $l : L : : \frac{a}{2} . \frac{La}{2l} = W$ half the weight of the greater beam.

Now the beam cannot break by its own weight, unless the weight of the beam be equal to the weight that will break it:

Wherefore, $\frac{La}{2l} = \frac{w+\frac{a}{2}}{L}l = \frac{2w+a}{2L}l \quad \therefore \quad L^2a = 2wl^2 + al^2,$

$\therefore a : 2w+a : : l^2 : L^2$, consequently $\sqrt{L^2} = L =$ the length of the beam that can just sustain its own weight.

Problem II. Having the weight of a beam that can just support a given weight in the middle, to find the depth of another beam similar to the former, so that it shall just support its own weight.

Let d=the depth of the first beam;
x=the depth of the second;
a=the weight of the first beam;
w=the additional weight that will break the first beam;

then will $w+\frac{a}{2}$ or $\frac{2w+a}{2}$ = the whole weight that will break the lesser beam.

And because the weights that will break similar beams are as the squares of their lengths,

$$\therefore d^2 : x^2 :: \frac{2w+a}{2} : \frac{2x^2 \times w + ax^2}{2d^2} = W$$

the weights of similar beams are as the cubes of their corresponding sides:

$$\text{Hence } d^3 : x^3 :: \frac{a}{2} : \frac{ax^3}{2d^3} = W$$

$$\therefore \frac{ax^3}{2d^3} = \frac{2x^2w + x^2a}{2d^2} \quad \therefore ax = 2wd + ad$$

$$\therefore a : a+2w :: d : x = \text{the depth required.}$$

As the weight of the lesser beam is to the weight of the lesser beam together with the additional weight, so is the depth of the lesser beam to the depth of the greater beam.

Note.—Any other corresponding sides will answer the same purpose, for they are all proportioned to one another.

Example. Suppose a beam whose weight is one pound, and its length 10 feet, to carry a weight of 399.5 pounds, required the length of a beam similar to the former, of the same matter, so that it shall break with its own weight.

here $a=1$
and $w=399.5$
then $a+2\ w=800=1+2\times 399.5$
$d=10$

Then by the last problem it will be $1:800:10:8000 = x$ for the length of a beam that will break by its own weight.

Problem III. The weight and length of a piece of timber being given, and additional weight that will break it, to find the length of a piece of timber similar to the former, so that this last piece of timber shall be the strongest possible:

Put l=the length of the piece given
w=half its weight,
W=the weight that will break it;
x=the length required.

Then, because the weights that will break similar pieces of timber are in proportion to the squares of their lengths,

$\therefore l^2 : x^2 :: W+w : \frac{Wx^2+wx^2}{l^2}$ = the whole weight that breaks the beam;

and because the weights of similar beams are as the cubes of their lengths, or any other corresponding sides,

then $l^3 : x^3 :: w : \frac{wx^3}{l^3}$ the weight of the beam;

consequently $\frac{Wx^2+wx^2}{l^2}$ less $\frac{wx^3}{l^3}$ is the weight that breaks the beam=a maximum; therefore its flexion is nothing.

$$\text{that is, } 2Wxx+2wxx-\frac{3wx^2x}{l}=\text{nothing.}$$

$$2W+2w=\frac{3wx}{l} \text{ therefore, } x=l\times\frac{2W+2w}{3w}$$

Hence it appears from the foregoing problems, that large timber is weakened in a much greater proportion than small timber, even in similar pieces, there-

fore a proper allowance must be made for the weight of the pieces, as I shall here show by an

Example. Suppose a beam 12 feet long, and a foot square, whose weight is three hundred pounds, to be capable of supporting 20 hundred weight, what weight will a beam 20 feet long, 15 inches deep, and 12 thick, be able to support?

12	square inches	15
12		15
144		75
12		15
12) 1728		225
144		12
		2.0)270.0
		135

But the weights of both beams are as their solid contents:

therefore 12	inches square
12	..
144	
144	inches=12 feet long
576	
576	
144	
20736	solid contents of the 1st beam

15 deep
12 wide

180
240 length in inches

7200
360

43200 solid contents of the 2d beam

20736 :43200 ::3
3

cwt. lb.
20736)129600(6 .. 28= the weight of the 2d beam
124416

5184
112

10368
5184
5184

20736)580608(28
41472

165888
165888

144::135::21.5 by prop. 1.

21.5

67.5
135
270

12)2902.5

12)241.875

20.25625
112

31250
15625
15625

17.50000
16

30
5

8.0

21 cwt. 56 lbs. is the weight that will break the first beam, and 20 cwt. 17 lb. 8 oz. the weight that will break the second beam; deduct out of these half their own weight.

20::17::8
3::14::0 half

17...3..8

Now 20 cwt. is the additional weight that will break the first beam; and 17 cwt. 3 lb. 8 oz. the weight that

will break the second: in which the reader will observe, that 10::3::8 has a much less proportion to 20, than 20 cwt. 17 lb. 8 oz. has to 21::46. From these examples, the reader may see that a proper allowance ought to be made for all horizontal beams; that is, half the weights of beams ought to be deducted out of the whole weight that they will carry, and that will give the weight that each piece will bear.

If several pieces of timber of the same scantling and length are applied one above another, and supported by props at each end, they will be no stronger than if they were laid side by side; or this, which is the same thing, the pieces that are applied one above another are no stronger than one single piece whose width is the width of the several pieces collected into one, and its depth the depth of one of the pieces; it is therefore useless to cut a piece of timber lengthways, and apply the pieces so cut one above another, for these pieces are not so strong as before, even if bolted.

Example. Suppose a girder 16 inches deep, 12 inches thick, the length is immaterial, and let the depth be cut lengthways in two equal pieces; then will each piece be 8 inches deep, and 12 inches thick. Now, according to the rule of proportioning timber, the square of 16 inches, that is, the depth before it was cut, is 256, and the square of 8 inches is 64; but twice 64 is only 128, therefore it appears that the two pieces applied one above another, are but half the strength of the solid piece, because 256 is double 128.

If a girder be cut lengthways in a perpendicular direction, the ends turned contrary, and then bolted together, it will be but very little stronger than before

it was cut; for although the ends being turned give to the girder an equal strength throughout, yet wherever a bolt is, there it will be weaker, and it is very doubtful whether the girder will be any stronger for this process of sawing and bolting; and I say this from experience.

If there are two pieces of timber of an equal scantling, the one lying horizontal, and the other inclined, the horizontal piece being supported at the points e and f, and the inclined piece at c and d, perpendicularly over e and f, according to the principles of mechanics, these pieces will be equally strong. But, to reason a little on this matter, let it be considered, that although the inclined piece D is longer, yet the weight has less effect upon it when placed in the middle, than the weight at h has upon the horizontal piece C, the weights being the same; it is therefore reasonable to conclude, that in these positions the one will bear equal to the other.

The foregoing rules will be found of excellent use when timber is wanted to support a great weight; for, by knowing the superincumbent weight, the strength may be computed to a great degree of exactness, so that it shall be able to support the weight required. The consequence is as bad when there is too much timber, as when there is too little, for nothing is more requisite than a just proportion throughout the whole building, so that the strength of every part shall always be in proportion to the stress; for when there is more strength given to some pieces than others, it encumbers the building, and consequently the foundations are less capable of supporting the superstructure.

No judicious person, who has the care of constructing buildings, should rely on tables of scantling, such as are commonly in books; for example, in story posts the scantlings, according to several authors, are as follows:

For 9 feet high 6 inches square

12———— 8
15————10
18————12

Now, according to this table, the scantlings are increased in proportion to the height; but there is no propriety in this, for each of these will bear weight in proportion to the number 9, 16, 25, and 36, that is, in proportion to the square of their heights, 36 being 4 times 9; therefore the piece that is 18 feet long, will bear four times as much weight as that piece which is 9 feet long; but the 9 feet piece may have a much greater weight to carry than an 18 feet piece, suppose double: in this case it must be near 12 inches square instead of 6. The same is also to be observed in breast-summers, and in floors where they are wanted to support a great weight; but in common buildings, where there are only customary weights to support, the common tables for floors will be near enough for practice.

To conclude the subject, it may be proper to notice the following observations which several authors have judiciously made, viz.: that in all timber there is moisture, wherefore all bearing timber ought to have a moderate camber, or roundness on the upper side, for till that moisture is dried out, the timber will swag with its own weight.

But then observe, that it is best to truss girders when they are fresh sawn out, for by their drying and shrinking, the trusses become more and more tight.

That all beams or ties be cut, or in framing forced to a roundness, such as an inch in twenty feet in length, and that principal rafters also be cut or forced in framing, as before; because all joists, though ever so well framed, by the shrinking of the timber and weight of the covering will swag, sometimes so much as not only to be visible, but to offend the eye: by this precaution the truss will always appear well.

Likewise observe, that all case-bays, either in floors or roofs, do not exceed twelve feet if possible; that is, do not let your joints in floors exceed twelve feet, nor your purlins in roofs, &c., but rather let their bearing be eight, nine, or ten feet. This should be regarded in forming the plan.

Also, in bridging floors, do not place your binding or strong joists above three, four, or five feet apart, and take care that your bridging of common joists are not above twelve or fourteen inches apart, that is, between one joist and another.

Also, in fitting down tie-beams upon the wall plates, never make your cocking too large, nor yet too near the outside of the wall plate, for the grain of the wood being cut across in the tie-beam, the piece that remains upon its end will be apt to split off, but keeping it near the inside will tend to secure it.

Likewise observe, never to make double tenons for bearing uses, such as binding joists, common joists, or purlins; for, in the first place, it very much weakens whatever you frame it into, and in the second place,

it is a rarity to have a draught to both tenons, that is, to draw both joists close; for the pin in passing through both tenons, if there is a draught in each, will bend so much, that unless it be as tough as wire, it must needs break in driving, and consequently do more hurt than good.

Roofs will be much stronger if the purlins are notched above the principal rafters, than if they are framed into the side of the principals; for by this means, when any weight is applied in the middle of the purlin, it cannot bend, being confined by the other rafters; and if it do, the sides of the other rafters must needs bend along with it; consequently it has the strength of all the other rafters sideways added to it.

This volume will be followed by at least three more, on the subject of **Carpentry and Joining**, one volume of which will be devoted to **Framing** and **Heavy Timbered Work**. The other two or more volumes will be devoted to fine joining and cabinet work, so far as the latter art comes within the purview of the joiners' work.

Each volume will, of course, be illustrated with diagrams and working details. The matter will be taken from executed works and from every available source.

MODERN CARPENTRY.

VOL. II.

ADVANCED SERIES.

The student will be expected to read carefully these papers before doing any work. His name and address will require to be given on each page. He will be expected to write up the questions in a neat and intelligent manner, using his own language and style, representing the answers in such a manner as will be intelligible, make all drawings as clear as possible, and wherever it can be done render them in India ink. Let each answer be original, do not copy others from the instruction paper, nor from any other source. The paper used may be of any kind, provided that it is clean and durable. Do not attempt an answer until you have thoroughly grasped the subject.

QUESTIONS.

1. Give definition of the term "Solid Geometry."
2. To what purposes may a knowledge of Solid Geometry be applied?
3. Explain what is meant by the horizontal projection of an object.
4. Show by sketch and describe the vertical projection (or elevation) and horizontal projection (or plan) of a table in the middle of an oblong room.

5. Explain what is meant by the elevation or vertical projection of an object.

6. What is the term given to a line that represents the angle formed by the wall and floor of a room?

7. Give an explanation of what is meant by the term "perpendicular."

8. Give an explanation of what is meant by the term "vertical."

9. Give a sketch and show how to determine the position and length of a given straight line, parallel to one of the planes of the projection.

10. Give a sketch and show how to determine the length of a given straight line which is oblique to both planes of projection.

11. Show by sketch and describe how to find the points wherein the prolongation of a right line would meet the planes of projection, when projections of same right line are given.

12. Show by sketch and describe how to find from the given projection of two lines that intersect each other in space, the angles which they make with each other.

13. Show by sketch and describe how to determine from the projection of two lines which intersect each other in the projections, whether the lines cut each other in space or not.

14. Show by sketch and describe how to find the angle made by a plane with the horizontal plane of projection.

15. When the traces of a plane and the projections of a point are given, show how to draw through the point a plane parallel to the given plane.

16. When the traces of two planes which cut each other are given, show by sketches and describe how to find their intersections.

17. When the traces of two intersecting pl
given, show by sketches and describe how to
angle which the planes make between them.

18. Show by sketches and describe how tl
given point to draw a perpendicular to a given

19. Show by sketches and describe how tl
given point to draw a plane perpendicular to
right line.

20. When a right line is given in projection
the traces of a given plane, show by sketches and
how to find the angle which the line makes
plane.

21. Show by sketch and describe how to
vertical projection of a regular tetrahedron
horizontal projection is given.

22. When a point is given in one of the proje
a tetrahedron, show by sketch and describe ho
the point on the other projection.

23. When a tetrahedron, and the trace of
(perpendicular to one of the planes of project
ting it, by which it is truncated, are given,
sketch and describe how to find the projectio
section.

24. When the projections of a tetrahedron a
show by sketch and describe how to find the pr
when inclined to the horizontal plane in any de

25. Show by sketch and describe how to
the vertical and horizontal projections of a
axes of which are perpendicular to the horizon

26. Show by sketch and describe how to
the projections of a regular octahedron, when
axes is perpendicular to either plane of projec

27. When one of the faces of an octahedron
coincident with the horizontal plane of projecti

by sketch and describe how to construct the projections of the solid.

28. When the projection of one of the faces of a dodecahedron is given in the horizontal plane, show by sketches and describe how to construct its projections.

29. When one of the faces of a dodecahedron is given, show by sketches and describe how to construct the projections of the solid, so that its axis may be perpendicular to the horizontal plane.

30. Show by sketches and describe how to inscribe a tetrahedron, a hexahedron or cube, and a dodecahedron, in a given sphere.

31. Show by sketches and describe how to find the vertical projection of the cylinder, when the horizontal projection, the axis of which is perpendicular to the horizontal plane, is given.

32. When the traces of one oblique plane are given, show by sketch and describe how to determine the inclination of the plane to both the horizontal position and the vertical position.

33. Show by sketches and describe how to construct the projections of the cylinder, when the base and also the angles which the base makes with the planes of projection, are given.

34. When a point in one of the projections of a cone is given, show by sketches and describe how to find it in the other projection.

35. Show by sketch and describe a helix on a given cylinder.

36. Show by sketch and describe a helix on a given cone.

37. When the point in one of the projections of the sphere is given, show by sketches and describe how to find it in the other projection.

38. When the projections of a regular tetrahedron are given, show by sketches and describe how to draw the section made by a plane perpendicular to the vertical plane and inclined to the horizontal plane.

39. When the projections of a hexagonal pyramid are given, show by sketches and describe how to draw the section made by a plane perpendicular to the vertical plane and inclined to the horizontal plane.

40. When the projections of an octagonal pyramid are given, show by sketches and describe how to draw the section made by a vertical plane.

41. Show by sketches and describe how to draw the section of a cylinder by a plane oblique to the axis.

42. In how many different ways may a cone be cut by a plane, and describe each separately, illustrated by sketch.

43. Give sketch and describe how to draw the section of a cone made by a plane cutting both its sides, i. e., an ellipse.

44. Give sketch and describe how to draw the section of a cone made by a plane parallel to one of its sides, a hyperbola.

45. Give sketch and describe how to draw the section of a cone made by a plane parallel to the axis, i. e., a hyperbola.

46. Give sketches and describe how to draw the section of a cuneoid made by a plane cutting both its sides.

47. Give sketches and show how to describe the section of a cylinder made by a curve cutting the cylinder.

48. Give sketches and show how to describe the section of a sphere.

49. Show how to describe the section of an ellipsoid when a section through the fixed axis, and the position of the line of the required section, are given.

50. Show how to find the section of a cylindrical ring perpendicular to the plane passing through the axis of the ring, the line of section being given.

51. Show how to describe the section of a solid of resolution, the generating curve of which is an ogee.

52. Show how to find the section of a solid of resolution, the generating curve of which is of a lancet form.

53. Show how to find the section of an ogee pyramid with a hexagonal base.

54. When the projection of two equal cylinders which intersect at right angles are given, show how to find the projections of their intersections.

55. Show how to construct the projections of two unequal cylinders whose axes intersect each other obliquely.

56. Show how to find the intersections of a sphere and a cylinder.

57. Show how to construct the intersection of two right cones with circular bases.

58. Explain the composition of the hexahedron or cube.

59. Explain the composition of the octahedron.

60. Explain the composition of the dodecahedron.

61. Explain the composition of the icosahedron.

62. Show wherein the operation consists in the development of a right pyramid of which the base and the height are given.

63. Show how the development is found in an oblique pyramid.

64. Show the results of the development of the faces and lines in a right prism.

65. Show the results of the development of the faces and lines when a prism is inclined.

66. Give the definition of a "cylinder."

67. Show how to find the covering of a righ
der.

68. Show how to find the edge of the coveri
cylinder when it is oblique in regard to the si

69. Show how to find the covering of a cylin
tained between two oblique parallel planes.

70. Show how to find the covering of a sen
dric surface bounded by two curved lines.

71. Show how to find the covering of the fru
a cone, the section being made by a plane perpe
to the axis.

72. Show how to find the covering of a se
dome.

73. Show how to find the covering of a semi-
dome.

74. Show how to find the covering of a semi-
dome when it is required to cover the dome horiz

75. Show how to find the covering of an
dome.

76. Show how to find the covering boards
ellipsoidal dome.

77. Show how to find the covering of an ell
dome in gores.

78. Show how to describe the covering of a
soidal dome with horizontal boards of equal wi

79. Show how to find the covering of an
vault.

80. Show how to find the covering of an oge
hexagonal in plan.

81. Show how to find the exact stretch out o
of a straight line that shall equal the quadra
semi-circle.

82. Show how to find the miters for inte
straight and circular mouldings.

83. Show how to find the form of a spring or solid moulding on any rake without the use of either ordinates or centers.

84. Show by sketch and describe what is meant by the projection of a solid.

85. Given the sides of a square bar which may be any length, the bar to stand perpendicular and pass through an inclined plank, show on the surface of plank the shape of a mortise that shall exactly fit the bar.

86. Show by sketch and describe the mode of constructing a bracketing ceiling under a roof.

87. Give sketch of a six-paneled ceiling and describe the best way of making panelled ceilings.

88. Show plan and section for a center suitable for a panelled ceiling and describe method of forming small ventilator for same.

89. Show by sketch and describe how to find the angle bracket of a cornice for interior and exterior, otherwise re-entrant and salient, angles.

90. Show by sketch and describe how to find the angle-bracket at the meeting of a concave wall with a straight wall.

91. Show by sketch and describe the method of finding the angle-bracket at the meeting of coves of equal height but unequal projection.

92. Show by sketch and describe the curb and ribs of a circular opening, cutting in on a sloped ceiling.

93. Show by sketch and detail how to describe a spherical niche on a semi-circular plan.

94. Show by sketch and detail how to describe a niche of which both the plan and elevation are segments of a circle.

95. Show by sketch and describe how to find t lengths and bevel of the ribs.

96. Show by sketch and describe a niche semi-ellip in plan and elevation.

97. Show by sketch and describe how to draw t ribs of an irregular octagonal niche.

99. Show by sketch in double curvature work a describe how to obtain to soffit mould for marking t veneer.

100. Show by sketch and describe how to form t head.

101. Show by sketch and describe how to obtain developed face mould.

102. Show by sketch and describe how to find mould for the cot bar.

103. Show by sketch and describe how to find mould for the radial bars.

104. Show by sketch and describe how to ma frame-splayed lining with circular soffit.

105. Show by sketch and describe how to obtain face moulds for the soffit stiles.

106. Show by sketch and describe how to apply moulds.

107. Show by sketch and describe a window with splayed soffit and splayed jambs.

108. Show by sketches and give description of h to enlarge and diminish mouldings.

109. Show by sketch and describe method of findi the true section of an inclined moulding that is require to miter with a similar horizontal moulding at its low end, as in pediments of doors and windows.

110. What is meant by "sprung mouldings"?

111. Show by sketch and describe the mitering straight and curved mouldings together.

112. Show by sketch and describe how to obtain the section of a sash bar raking in plan.

113. Give the different names applied to interior shutters.

114. Give the different names applied to exterior shutters.

115. Give a description of the folding or boxing shutters.

116. Give sketch of a sectional elevation of a window fitted with boxing shutters.

117. Give a description of sliding shutters.

118. Give a description of balanced or lifting shutters.

119. Give a description of rolling or spring shutters.

120. Give description of the details in construction of windows.

121. Give description of the joints of window sashes.

122. Give description of "casement windows" in general.

123. Give description of casement sashes opening inward.

124. Show by sketch the elevation and vertical and horizontal sections of a window in a 14-inch brick wall fitted with a casement window having folding sashes to open inwards.

125. Give description of casement sashes opening outwards, and sketches to illustrate same.

126. Give description of details in the construction of a sash and frame window, also sketches to illustrate same.

127. Describe what is meant by a "double-hung sash and frame window."

128. Describe what is meant by a "single-hung sash and frame window."

129. Give description of a "Venetian window."

130. Give description of the hanging of vertical sliding sashes.

131. Give description of a "bay window," also show sketches of elevation and vertical section of same.

132. Give description of a window with curved head, also sketch showing the outside and inside elevations.

133. Give descriptions of the three ways how the arch may be formed when the head of the frame has to be curved.

134. Give description of the construction of "store-windows."

135. Give sketches showing the front elevation also vertical and horizontal sections of a store-window.

136. Give sketch of part of a sash and frame window, showing panelled and moulded jamb lining, etc.

137. Give description of the "window linings," of the "Architrave or Band Moulding" of the "Grounds" and "Window Board."

138. Give description of "window shutters."

139. Give details of the construction of "box shutters."

140. Give details of the construction of "sliding shutters."

141. Give details as to the fitting of hinged skylights.

142. Give details in the construction of "Dormer windows."

143. Give details in the construction of "large skylights."

144. Give details in the construction of "lantern lights."

145. Give details in the construction of "Lay-lights."

146. Give description of how "Greenhouses and Conservatories" are constructed.

147. Give description of the construction of a "Bay window" with solid frame, and casement lights, also sketches showing plan, sections and elevations of same.

148. Give description of the construction of a "cased frame bay window," also sketches showing half plan, half inside elevation, and central vertical section of same.

149. Give description of a "pivoted light" and its construction, also sketches of elevation and section of a pivot-hung sash.

150. Give details of how to hang the sash of a "pivot-light."

151. Describe how to find the position to cut the beads for a "pivot-light."

152. Describe the construction of a "bull's eye" frame with a pivoted sash, and give sketches of plan, and section of same.

153. Describe the construction and laying out of a "circular louvre" and give sketches illustrating same.

154. Give the names applied to the different kinds of doors.

155. What are the essential qualities in the design and construction of doors?

156. Describe "battened and battened frames and braced doors" and give sketches illustrating same.

157. Describe the construction of the plain "battened door" and give sketches of the "back elevation" and "vertical section" of same.

158. Describe the construction of the "framed bat-

tened and braced door" and give sketches of the "back elevation" and "vertical section" of same.

159. How are "framed or panelled doors" distinguished?

160. What is meant by the term "square and sunk"?

161. What is meant by the term "moulded and square"?

162. What is meant by the term "bead-flush"?

163. What is meant by the term "bead-butt"?

164. What is meant by the term "raised panel"?

165. What is meant by the term "the chamfered panel"?

166. What is meant by the term "raised and flat or raised and fielded?"

167. What is meant by the term "raised, sunk, and fielded"?

168. What is meant by the term "raised, sunk and moulded"?

169. What is meant by the term "stop-chamfered"?

170. What is meant by the term "bolection moulded"?

171. What is meant by the term "double bolection moulded"?

172. Give the constructive memoranda for doors.

173. Give sketch of a panelled door showing top and bottom rails, middle or lock rail, top and bottom munting, stile, and top panels (one bead and flush) and (one square and sunk) and bottom panels (one moulded and square) and (one bead butt) also vertical section of door.

174. Give sketches and describe how "bead flush" panels are commonly made.

175. Describe construction of "bead butt" panels.

176. Describe construction of "bolection mouldings."

177. What are the usual dimensions given to ordinary good class dwelling house doors: Entrance doors, reception room doors, and bedroom doors, respectively?

178. Give details in construction of interior doors.

179. Give the names of usual kinds of timber employed in the construction of doors, and to which class respectively.

180. Give details as to the arrangement of members in the construction of doors.

181. What are "double-margined doors" and when are they generally adopted?

182. Describe the construction of "double-margined doors."

183. Give sketches and describe how to "set out" the bevelled shoulders of the stile and rail of a "diminished stile door."

184. Give description of how to "set out" the rail.

185. Give sketch of a "Gothic door" and describe its construction.

186. Give sketches of "revolving doors" and describe their construction.

187. Give description of the construction of "panelled framing" and where adopted.

188. Give description of "superior doors" where two kinds of wood are used in their construction.

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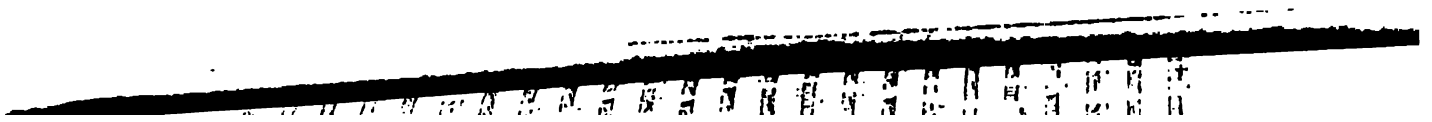
STEEL SQUARE

PART I



PREFACE

In 1872 I contributed to a mecnanical journal a few short papers on "The Use of the Carpenter's Steel Square." A few years later, i.e., 1875-77, I wrote on the same subject a series of papers for "The American Builder," the most prominent building magazine at that time published in America. These papers, I am led to believe, were among the first that were ever issued devoted entirely to describing the uses and applications of the square, and so well did they meet with the appreciation of workmen who were interested in the steel square, that the writer was urged personally and by letters from all sides to put the papers in book form, and this was done in 1879, with the result that several hundred thousand copies of the work have been sold, and the demand has not yet decreased.

Since the first appearance of the little book above named the writer has been requested by hundreds of the readers thereof to still further pursue the subject and embody in one work all that is known of the square and that can be accomplished with it so far as can be gathered

up to the present time. Partly in response to this request, and partly because I am informed of several other writers having intimated their intentions of filling the gap if I failed to do so, I have been persuaded to prepare the following volumes, which I hope will be of sufficient value and contain enough merit to warrant the appreciation of all workmen who may have on some occasion or other, to make use of the steel square.

It is not necessary for me in this preface to remind the young workman of to-day of the necessity of arming himself with all the resources of modern methods and appliances for the performance of his work, if he desires to stand in the front rank of his trade. This is so evident that he who runs may read it on every street corner. It is the bright, well-informed young man that wins the race, and the fellow who drops his tools at the first clang of the bell at quitting time and gives no further thought either to his work or his tools until the commencement of work again the following day, always remains at the foot of the ladder, and wonders how it is he does not prosper and thrive at the same rate as his more energetic and studious fellow workman. A few hours' quiet study each week during the winter nights

makes the difference between poverty and sufficiency, for be it known the employer soon discovers the superior qualities of the man who employs his brains as well as his hands in the performance of his duties, and advancement and higher pay are sure to follow sooner or later.

In the whole course of practice in the building arts there is no tool the artisan possesses that lends itself so readily to the quick solution of the many difficult problems of laying out work as the steel square. Therefore, it is essential the workman should have a thorough practical knowledge of its capabilities and applications, and it is to aid him in acquiring that knowledge that this work is prepared. It will be my endeavor throughout to place everything presented in as simple and plain a manner as possible, and avoid mystifying the workman with a redundance of formulae and figures, giving graphic explanations where possible, and cutting out surplus figures where such can be done without vitally affecting the sense of the subject under discussion.

As a matter of course I have drawn from many recent writers on the steel square, both as regards illustrations and descriptions, and in a number of instances it may be necessary for

me to repeat the solutions of some problems, showing different methods employed by different writers to arrive at the same results; and in doing this I am anxious to give credit to each individual whose matter I have made use of. It will be impossible, however, to give credit in each case, so I give the names herewith, and, should I omit any, I will be pleased to hear of them, and will see they are not overlooked in the next edition. The first in importance are J. O'Connell, St. Louis, Mo.; Wm. Croker, Orillia, Ontario; Wm. E. Hill, Terre Haute, Ind.; A. W. Wood, Lincoln, Neb.; F. Lascy, San Francisco, Cal.; J. P. Hicks, Omaha, Neb.; E. Stoddard, Indianapolis, Ind.; W. George, England; J. R. Gill, Hamilton, Ontario; W. G. Penrose, Trafford Park, England; H. Parker, England, and H. D. Cook, Philadelphia. Besides these a number of papers and magazines have been laid under contribution for matter and illustrations that are embodied in this work, among which may be mentioned the following: "The American Builder," "The Builder and Woodworker," "Scientific American Supplement," "Canadian Mechanics' Magazine," "Carpentry and Building," "California Architect," "National Builder," "Illustrated Carpenter and

ler" (English), "The Carpenter," and 'The
ing World," and one or two other journals.
ny of the items taken from the foregoing
been changed, corrected and simplified,
)ut in such a shape that the ordinary work-
will find but little difficulty in grasping
to such an extent as to render them
l.

)resenting a work of this kind to the public
ıthor feels that he is making a somewhat
dous venture, as he must naturally go over
ıt deal of ground that has been trodden by
s, and it may be thought by many that a
portion of the matter put forth is a work
ererogation. It must be remembered, how-
that a new generation "that knew not
h," crops up every few years, and it is for
and for future generations that this work
ıpiled and written, while it contains much
s new and much that will be acceptable to
men now engaged in the building arts.

: author begs it to be understood that no
y merit is claimed for this work. Practical
offer but little opportunity for literary
e. To be exact, practical, clear and concise
haps the best that can be expected in a
of this kind, and, if I succeed on these

grounds and have so couched my language that the ordinary practical mind of the working man can thoroughly understand what I have meant to convey, I shall be well satisfied. So far as the financial success of the work is concerned past experience on these lines assures me of favorable results, and for this I am pleased for the publishers' sake, as they have advised me to "spare no expense" in making this book a "standard" for all time. Whether my humble abilities are equal to the task will be for the public to say. However, be this as it may, if the work fails of being what it is intended it will not be because of any parsimony on the publishers' behalf, but rather because of the inability of the author and compiler.

FRED T. HODGSON,
COLLINGWOOD, ONTARIO.

PREFACE TO SECOND EDITION.

VOLUME I.

It is now more than six years since the first edition of this work was published, and during that time the author and publisher have received thousands of inquiries and requests regarding an extension and enlargement of the work, and because of these, and because of a desire to keep this and the second volume of the work up to date and abreast with modern requirements, we feel the time has arrived when new additional matter, problems, diagrams, and explanations are become necessary. To accomplish this, we have introduced in this edition, many new "Steel Square Kinks," and remodeled some of the previous work, and added a new feature in the shape of some very interesting problems in handrail construction, which we are sure will prove instructive reading matter, and will make this treatise on "The Steel Square and Its Uses," an exhaustive Cyclopedia of everything worth knowing in connection with this magical tool.

The hundreds of thousands of copies of the first edition of this work that are now in the hands of workmen and others, will not have their value impaired one whit, because of this new edition being placed on the market, as it will not detract from the usefulness of the first edition, and the new matter embodied in the present edition may be obtained at any time if considered necessary.

If the present edition meets with anything like the same favor the earlier edition enjoyed, both author and publisher will feel these have been made in the right direction.

FRED T. HODGSON.

Collingwood, Ontario,

THE STEEL SQUARE

INTRODUCTION

While it is not intended to give a history of the steel square as far as known, it may not be amiss to say a few words regarding the origin of this useful tool. It is quite evident that many of the prehistoric races understood the use of a square of some kind, for in many of the old buildings and monuments that have come down to us from the time before writing was known, evidences of material having been "squared" are as numerous as the old ruins themselves. It is on record that a whole "kit" of carpenters' tools, with a square included, was found in an Egyptian tomb, dating four or five thousand years before Christ. This is a hoary antiquity, and disposes of the claim made by the Greeks that the tool was the invention of one Theodosius, a Greek, of Samos. Theodosius evidently was a mechanic and artist of some note, and may have improved the square, but he certainly never invented it. The steel square, however, as we know it, is of comparatively modern growth. The predecessor of the present

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square was a clumsy iron tool, with a blade about 1½ inches wide, and a tongue about 1 inch wide. I say "about" because the squares were not by any means exact in their dimensions, or in their "truthfulness," and were not made use of by mechanics doing fine work, but were chiefly confined to blacksmith shops and similar places. Their marking and figuring were irregular and often incorrect and unreliable. These squares were mostly made in England, though I have seen a few that were manufactured in Belgium or France.

The first squares manufactured from steel and made with a 2-inch blade and 1½-inch tongue, so far as I have been able to discover, were made early in the nineteenth century near New Haven, Conn. These, however, were very crude affairs and not well figured. I have been told that steel squares, with a blade 2 feet long and 2 inches wide and tongue 1 foot 6 inches long and 1½ inches wide, were made in Sheffield one hundred and fifty years ago, and that some of these squares are still in existence, though I have not seen one nor have I any reliable evidence that such squares exist or ever did exist. Coming down to our own day, however, we are now well supplied with steel squares of fine quality

and perfect and accurate make. Indeed, there are "squares and squares," some of them being paragons of simplicity, while others are as wonderfully and fearfully made as the human structure, yet all of them possess some quality or qualities that justify their manufacture and insure a profitable return to the makers thereof.

Before entering into the more serious part of the subject under consideration I purpose giving a description of a number of squares that are now in the market, along with the manufacturer's directions for their use, and further, I also intend to illustrate and describe some of the charts, diagrams, keys and rules that have lately been devised, for the purpose of assisting the student in understanding the application of the square for the solving of roof and other problems.

The illustration shown at Fig. 1 represents a square and its attachments in elevation, of a recent invention, and Fig. 2 gives a view of its edge. A is a carpenter's square made of metal in the ordinary form with the outer edges graduated in inches and sixteenths, and the inner edges in inches and twelfths. The straight edge or stock, B, is in two parts, one upon each side of the square as shown in Fig. 2. These two parts

the square represent the length of the rafters, and this space may be read off on the scale of the stock where this scale is cut by the short arm of the square.

When the implement is thus adjusted to determine the length of a rafter the shorter arm, *a*, will give the bevel for the upper end, and the longer arm, *b*, of the foot, as shown in Fig. 5.

Fig. 3 illustrates the mode of adjusting the implement to be used as a miter, and Fig. 4 shows the manner in which it may be used for laying out stairs; one limb giving the angle for the treads and the other for the risers.

This is called a "pitch-square," being especially designed for laying out roofs.

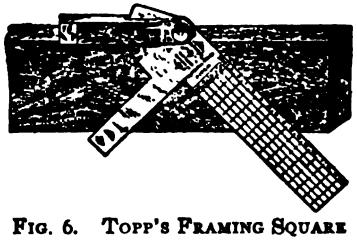

FIG. 6. TOPP'S FRAMING SQUARE

The "Topp's Framing Tool," Fig. 6, is another very curious and very ingenious square, and is intended as a sort of "ready-reckoner," as it contains on its blades rules for laying off nearly every kind of rafter, hip, valley and jack. The illustration shown gives some idea as to the style of square. It is claimed by the inventor, Mr. G.

ical Uses of the Steel Square

We now take up a square void of any attachments, and one which has become quite popular in the west and the middle southern states. I refer to the "Nicholls Square," a representation of one side of which is shown at Fig. 8. This square is a new one on the market, and presents some advantages over many now being sold. The manufacturers direct special attention to the fact that the board measure has been replaced by a simple rule for framing, and that there is to be found the lengths and figures giving the cuts for an entire roof, also the cuts for cornice of the same. The tongue on the square is 1¾ inches wide, thus making it convenient for spacing, as much of the dimension lumber is 1¾ inches thick. The general directions for using this square—a copy of which is given to every purchaser of a square—are pre-

said members, and the edge opening *e* formed in the edge of said frame perpendicular to said side, in combination with leveling glasses inclosed longitudinally in said members and exposed through said openings, substantially as set forth.

2. "The described level, square and plumb, comprising the integral members A and B at right angles to each other, formed with longitudinal perforations and with surface openings thereto, in combination with the leveling glasses C, D and E in said perforations, two of said glasses lying parallel in the head A, and the other being perpendicular thereto in the blade B, substantially as set forth."

There are several other combination squares on the market, one known as the "Van Nam[illegible] Framing Square," which possesses considerable merit,—but I fear it would be taking up too much space and making too great an inroad into the readers' time to describe more of them.

We now take up a square void of any attachments, and one which has become quite popular in the west and the middle southern states. I refer to the "Nicholls Square," a representation of one side of which is shown at Fig. 8. This square is a new one on the market, and presents some advantages over many now being sold. The manufacturers direct special attention to the fact that the board measure has been replaced by a simple rule for framing, and that there is to be found the lengths and figures giving the cuts for an entire roof, also the cuts for cornice of the same. The tongue on the square is 1¾ inches wide, thus making it convenient for spacing, as much of the dimension lumber is 1¾ inches thick. The general directions for using this square—a copy of which is given to every purchaser of a square—are pre-

sented herewith, so that the reader will be able himself to judge of the merits of the tool. These squares are numbered or graded according to the graduation marks and quality of finish.

"The face of a square is the side on which we stamp our name. The reverse is the back. The longer arm is the body, the other is the tongue.

Framing Rule.—The first line of figures gives the length of common rafters for one foot run.

The second line of figures gives the length of hip or valley rafters for one foot run.

The third line of figures gives the length of first jack rafter and the difference in the length of the others spaced 16 inches on centers.

The fourth line of figures gives the length of first jack rafters and the difference in the length of the others spaced 2 feet on centers.

The fifth line of figures gives the side cut of jack rafters against hip or valley rafters.

The sixth line of figures gives the side cut of hip or valley rafter against ridge board or deck.

The seventh line of figures gives the cuts of sheathing and shingles in valley or hip, for example:

1. If your roof is raised 8 inches to the foot, or, as it is called, third pitch, under 8 on the first line are the figures 14.42. This is the length of

common rafters for one foot run. If the building is 16 feet wide half the width of building would be the run of common rafter. In this case it would be 8; multiply 14.42 by 8, you have 115.36 inches, or 9 feet 7¾ inches.

2. To obtain the bottom and top cuts of common rafter use the figures 12 on body and 8 on tongue; 12 side gives bottom cut, 8 side gives top cut; the same figures give bottom and top cuts for jack.

On the second line under 8 are the figures 18.78; multiply these figures by 8, which is the run of the common rafter. This gives 150.24, or 12 feet 6¼ inches. This is the correct length of hip or valley rafter. To obtain the bottom and top cuts for hip or valley rafters, use the figures 17 on body and 8 on tongue; 17 side gives bottom cut, 8 side gives top cut.

This is all the figuring necessary to be done. The reason for giving the lengths for one foot of common and hip or valley rafters is that it will work in all cases regardless of width of buildings.

3. On the third line under 8 are the figures 19¼ inches. This is the length of first jack rafter, also the difference in the length of the others spaced 16 inches on centers. For example, the

first jack being 19¼ inches, the second jack would be 3 feet 2½ inches; make each one 19¼ inches longer than the other.

On the fourth line under 8 are the figures 2 feet 4⅞ inches. This is the length of the first jack rafter, and the difference in the length of the others spaced 2 feet centers.

On the fifth line under 8 are the figures 10 and 12. By placing square on stock to be cut at these figures 10 on body, 12 on tongue, and marking on 12 side this gives side cut of jacks against hip or valley rafter.

On the sixth line under 8 are the figures 9 and 10. By placing square on stock to be cut at these figures, 9 on body and 10 on tongue, and marking on the 10 side, this gives side cut of hip or valley rafter against ridge board or deck.

On the seventh line under 8 are figures 12 and 10. By placing square on stock to be cut at these figures 12 on body, 10 on tongue, and marking on the 10 side this gives the cut of sheathing and shingles in valley or hip.

Remarks.—To obtain the lengths and cuts be careful to use the figures under whatever figure your roof raises to the foot. If your roof raises 12 inches to the foot, or half pitch, look under 12, and so on in all cases. In cutting jack

rafters allow for half the thickness of hip or valley rafters as lengths given on square are to center lines.

Note.—The figures on the square, giving side cuts of jacks, will also give the correct miter cuts for moulding in the valley at the junction of two gables, also miter cuts for gable mouldings where it intersects with level mouldings at the end of building.

The figures giving cuts of sheathing in valley or hip also give cuts for mitering level plancier with gable plancier, also the miter cuts where two gable planciers intersect, also the cut for plancier on gable end.

To obtain the bottom and top cuts of hip or valley rafter use the figure 17 on body, and whatever figure your roof raises to the foot on tongue. This will give you the correct cuts in all cases.

To obtain the bottom and top cuts of common rafters and jack rafters use the figure 12 on body, and whatever figure your roof raises to the foot on tongue. This gives correct cuts in all cases. Always remember that the cut comes on the tongue, or last named figure. It is so arranged in all cases.

Octagon, "Eight-square" Scale.—This scale is

along the middle of the face of the tongue, is used for laying off lines to cut an "e square" or octagon stick of timber fron square.

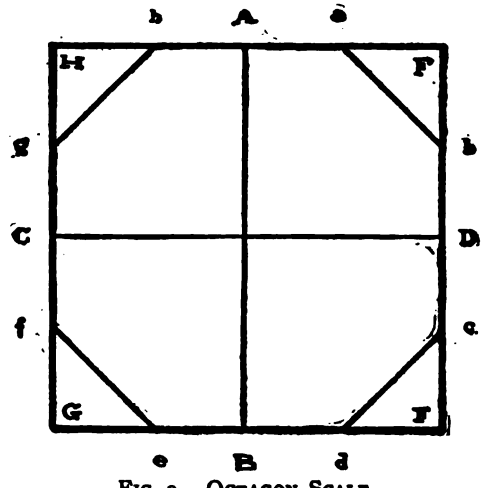

FIG. 9. OCTAGON SCALE

Suppose the figures A, B, C, D, Fig. 9, is butt of a square stick of timber 6x6 inc Through the center draw the lines AB and parallel with the sides and at right angles each other.

With the dividers take as many spaces from the scale as there are inches in the wi of the stick, and lay off this space on either s of the point A as Aa and Ab; lay off in the sa way the space from the point B as Bd and

also Cf and Cg and Db and De. Then draw the lines ab, ed, ef and gh. Cut off the solid angle E, also F, G and H; there is left an octagon, or "eight square" stick. This is nearly exact.

Brace Measure.—This is along the center of the back of the "tongue," and gives the length of the common brace.

‡ 25.45 in the scale means that if the run is 18 inches on the post and the same on the beam, then the brace will be $25\frac{44}{100}$ inches.

If the run is 21 inches on both beam and post, then the brace will be $29\frac{70}{100}$ inches.

Care of Square.—Never use emery or sand paper on nickel or black finished squares. When through using put on a few drops of oil. Do not put your square away with finger marks on it; nothing rusts it so quickly as perspiration."

It will be seen that these squares adapt themselves to other work as well as to framing, a quality very few of the combination squares possess, and while combination squares have their special uses and should be in the tool chest of every expert workman, the square pure and simple, like this of Nicholls or similar ones, should ever be absent from the "kit" of the ordinary workman, for with it, if he thoroughly understands it, he can accomplish all that is possible

even with a combination square. If he is

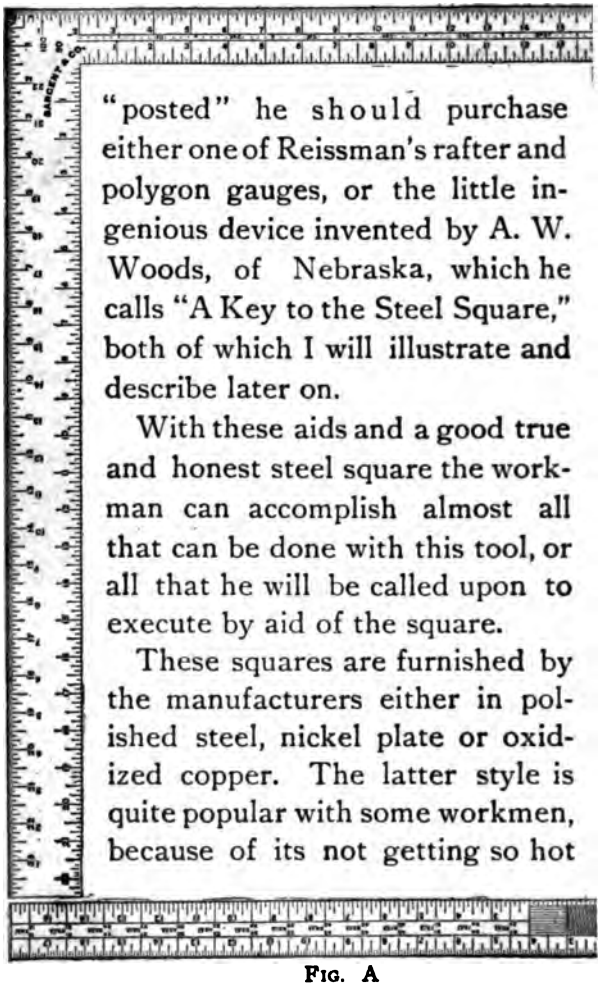
"posted" he should purchase either one of Reissman's rafter and polygon gauges, or the little ingenious device invented by A. W. Woods, of Nebraska, which he calls "A Key to the Steel Square," both of which I will illustrate and describe later on.
With these aids and a good true and honest steel square the workman can accomplish almost all that can be done with this tool, or all that he will be called upon to execute by aid of the square.
These squares are furnished by the manufacturers either in polished steel, nickel plate or oxidized copper. The latter style is quite popular with some workmen, because of its not getting so hot

FIG. A

when exposed to the rays of the sun.

The two sides of the square, shown at Fig. A, represent the carpenters' popular square, No. 100. This square has been a special favorite with workmen for nearly thirty years, and is still looked upon by many as being the *ne plus ultra* of steel squares. I show both sides of the square in order to enable the workman to see, before he buys, the kind of tool he will get. Like the Nicholls square, this may be obtained in polished steel, nickel plated, or oxidized copper as the purchaser may desire.

I show the complete square, reduced to page size. Sometimes this square is catalogued by dealers as No. 1000, practically, however, it is the same square as the No. 100. If we examine this square we will find on the tongue near its junction with the blade a series of lines and cross lines (see Fig. 10), making a figure known as the "diagonal scale." This scale is drawn to a larger size at Fig. 10*a*, and is shown alone and is used for taking off the

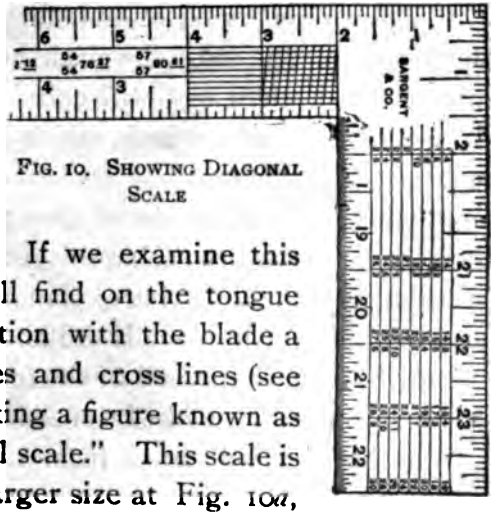

FIG. 10. SHOWING DIAGONAL SCALE

hundredths of an inch. The line *ab* is here an inch long, and is divided into ten equal parts; the line *cd* being also divided into ten equal parts, and diagonal lines are then drawn connecting the points as shown in the diagram. Suppose we wish to take off $\frac{16}{100}$ of an inch, we proceed as follows: Count off seven spaces from *c*, *e*, *g*, which equals $\frac{70}{100}$ of an inch; then count up the diagonal line until the sixth horizontal line, *e*, is reached, when *e f* will equal the required distance of $\frac{16}{100}$ of an inch, which is a trifle over ¾ of an inch.

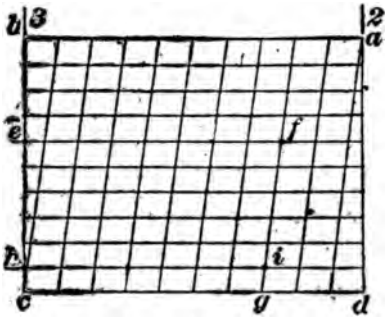

FIG 10*a* ENLARGED DIAGONAL SCALE

Quoting from the table of directions given in Sargent's circular describing this square, we have, for rafter cuts, the following explanation: "The run of a rafter set up in place is the horizontal measure from the extreme end of the foot to a plumb-line from the ridge end—from A to B, Fig. 11.

"The rise is the distance from the top of the ridge end of the rafter to the level of the foot. From C to D, Fig. 12.

"The pitch is the proportion that the rise

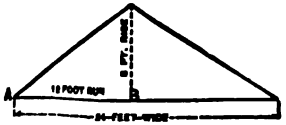

FIG. 11. SHOWING RAFTER RUN

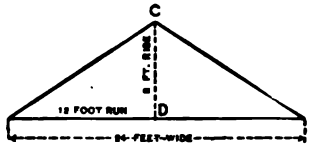

FIG. 12. SHOWING RAFTER RISE

bears to the whole width of the building. The illustration, Fig. 13, shows one-third pitch; the rise of 8 feet being one-third of the width of the building.

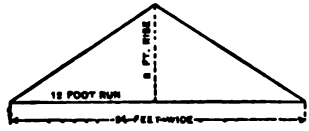

FIG. 13. SHOWING ROOF PITCH

"The cuts or angles of a rafter are obtained by applying the square so that the 12-inch mark on the body and the mark on the tongue that represent the rise shall both be at the edge of the rafter. The illustration, Fig. 14, shows 8 foot rise, the line A the cut for the ridge end of the rafter and B the cut for foot end."

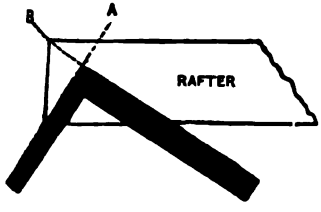

FIG. 14. SHOWING METHOD OF OBTAINING CUTS AND BENDS

The portion of square shown at Fig. 15 exhibits the tool having on its face a table of the run, rise and pitch of rafters, being specially figured for this purpose, and shows the measure

of the rafter for any one of seven pitches of roof

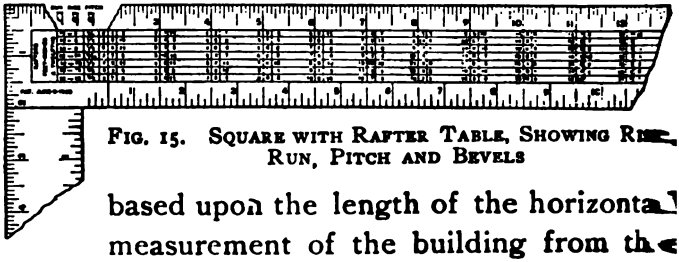

FIG. 15. SQUARE WITH RAFTER TABLE, SHOWING RISE, RUN, PITCH AND BEVELS

based upon the length of the horizontal measurement of the building from the center to the outside.

The following table, which was prepared especially for this square, shows the manner of working the square:

RAFTER TABLE DIRECTIONS

The rafter table and the outside edge of the back of the square, both on body and tongue, are in twelfths. The inch marks may represent inches or feet, and the twelfth marks may represent twelfths of an inch or twelfths of a foot (that is, inches) as a scale. The rafter table is used in connection with the marks and figures on the outside edge of the square.

At the left end of the table are figures representing the *run*, the *rise* and the *pitch*.

In the first column the figures are all 12, which may be used as 12 inches or 12 feet, and they represent a *run* of 12.

The second column of figures is to represent various *rises.*

The third column of figures in fractions represents the various *pitches.*

These three columns of figures show that a rafter

with a run of 12 and a rise of 4 has ⅙ pitch,
with a run of 12 and a rise of 6 has ¼ pitch,
with a run of 12 and a rise of 8 has ⅓ pitch,

and so on to the bottom of the figures.

To Find the Length of a Rafter.—For a roof with ⅙ pitch (or the rise ⅙ the width of the building) and having a run of 12 feet, follow in the rafter table the upper ⅙ pitch ruling, find under the graduation figure 12 the rafter length required, which is 12 7 10, or 12 feet and 7⅚ inches.

For ⅓ pitch (or the rise ⅓ the width of the building) and run 12 feet, the rafter length is 16 11 8, or 16 feet 11⅔ inches.

If the run is 25 feet, add the rafter length for run of 23 feet to the rafter length for run of 2 feet.

When the run is in inches, then in the rafter table read inches and twelfths instead of feet and inches. For instance:

If with ½ pitch the run is 12 feet 4 inches, add

the rafter length of 12 feet to that of 4 as follows:

For run of 12 feet the rafter length is . . . . . 16 feet $11\frac{8}{11}$

For run of 4 inches the rafter length is . . . . . $5\frac{8}{11}$

Total . . . . . 17 feet $5\frac{8}{11}$

The brace measure on these squares the center of the back of the tongu gives the length of the common braces a in Fig. 16. Examples are shown in the l at the point marked 24 30, which 24 inches on the post and 18 inches on th or girt, which make the brace 30 inch from point to point according to the rul

FIG. 16. SHOWING BRACE RULE

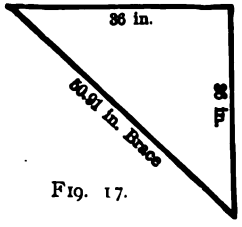

FIG. 17.

An application of this shown at Fig. 17, wh inches are laid off c post and beam, which gives the length brace from point to point 50.91 inches, nearly 4 feet 3 inches. Other dimensi

shown in the square. There is also a scale of one-hundredths, or one inch divided into 100 equal parts.

The octagon scale on this square runs along the middle of the face of the tongue, and is used for laying off lines to cut an "eight square" or octagon stick of timber from a square one.

Suppose the figure ABCD (see Fig. 9) is the butt of a square stick of timber 6x6 inches. Through the center draw the lines AB and CD parallel with the sides and at right angles to each other. With a pair of compasses take as many spaces (6) from the scale as there are inches in the width of the stick, and lay off this space on either side of the point A, as Aa and Ab; lay off in the same way the same space from the point B as Bd, Be; also Cf, Cg and Db, Dc. Then draw lines ab, cd, ef and gh. Cut off the solid angle E, also F, G and H. This will leave an octagon, or eight-sided stick, which will be found nearly exact on all sides.

The board measure, known as the "Essex Board Measure," Fig. 17½ is made use of in figuring these squares, and is used as follows: Figures 12 and 17 in the graduation marks on the outer edge represent a one-inch board 12 inches wide, which is the starting point for all calculations.

The smaller figures under the 12 represent the length.

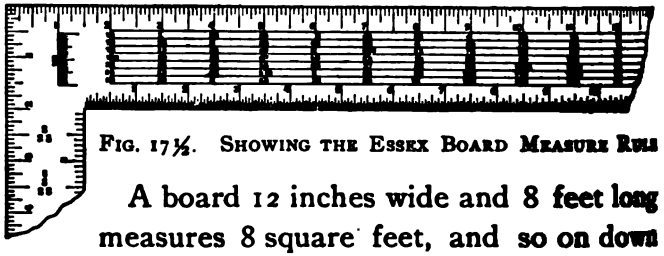

FIG. 17½. SHOWING THE ESSEX BOARD MEASURE RULE

A board 12 inches wide and 8 feet long measures 8 square feet, and so on down the table. Therefore, to get the square feet of a board 8 feet long and 6 inches wide, find the figure 8 in the scale under the 12-inch graduation mark and pass the pencil along to the left on the same line to a point below the graduation mark 6 (representing the width of the board), and you stop on the scale at 4, which is 4 feet, the board measure required. If the board is the same length and 10 inches wide, look under the graduation mark 10 on a line with the figure 8 before mentioned, and you will find $6\frac{8}{12}$ feet board measure; if 18 inches wide then to the right under the graduation mark 18, and 12 feet is found to be the board measure. If 13 feet long and 7 inches wide, find 13 in the scale under the 12-inch graduation and on the same line under the 7-inch graduation will be found $7\frac{7}{12}$ feet board measure. If the board

half this length, take half of this result; if ouble this length, then double this result. For iff 2 inches thick double the figures.

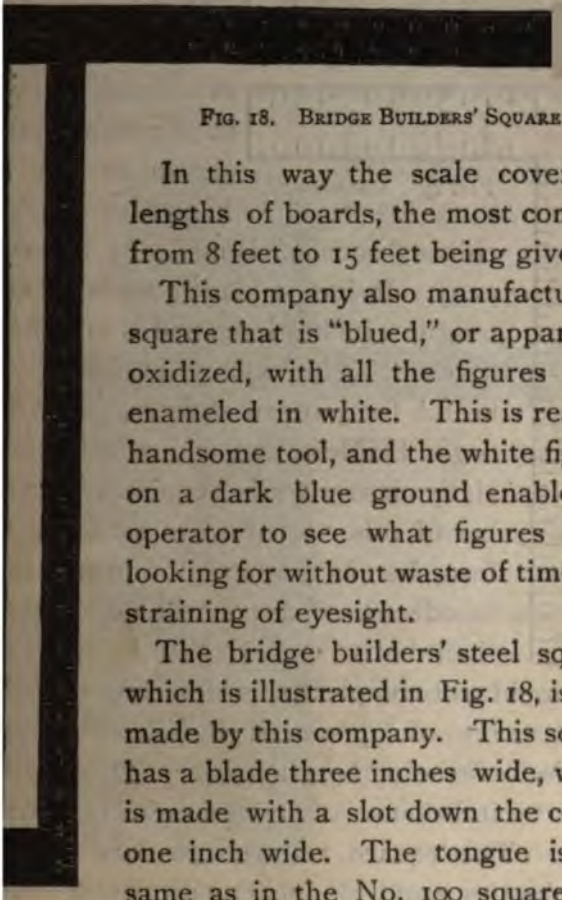

FIG. 18. BRIDGE BUILDERS' SQUARE

In this way the scale covers all lengths of boards, the most common from 8 feet to 15 feet being given.

This company also manufactures a square that is "blued," or apparently oxidized, with all the figures on it enameled in white. This is really a handsome tool, and the white figures on a dark blue ground enable the operator to see what figures he is looking for without waste of time and straining of eyesight.

The bridge builders' steel square, which is illustrated in Fig. 18, is also made by this company. This square has a blade three inches wide, which is made with a slot down the center one inch wide. The tongue is the same as in the No. 100 square, but no figures for brace or octagon rules. It is

not so handy for general purposes as
lar square, but for special purposes i
building, or for laying out very heav
structures it has special advantages,
shoulders and 3-inch tenons and mortis
readily lai
it. Anoth
shown in
known as
chinists' square," is made by
pany. It has a blade 6 inch
tongue 4 inches long, and is v
finished. This square is fo
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cially close work is required.
ber of other squares are mad
firm, but as they are not int
woodworkers' use I will not
them here.

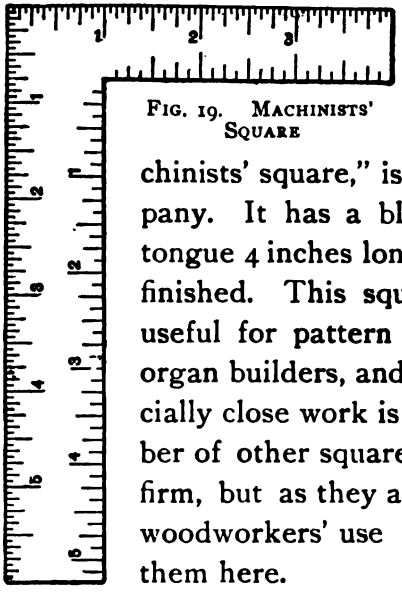

FIG. 19. MACHINISTS' SQUARE

I would not complete this descriptio
gent's make of squares if I failed
mention of their "bench square." I
name to it because of its fitness for b
poses. The square referred to has
12 inches long and 1½ inches wide, and
9 inches long and 1 inch wide. The fi

it is divided into inches, half inches, quarter inches, eighths and sixteenths of an inch. This is a very handy square for bench and jobbing purposes, and can be used in many places where the larger tool is unavailable, and may on emergency be employed for laying out rafters, braces and similar work.

FIG. 20. CRENALATED SQUARE

A square that was quite popular some sixteen or eighteen years ago known as "The Crenalated Square," an illustration of which is shown in Fig. 20, is still preferred by many workmen. The peculiarity of this square is that the inner edge of the tongue is notched, or crenalated, as shown in the illustration, the notches being intended as "gauge-points," where a sharpened pen-

cil may be inserted, then the square may drawn along the timber or board, with the bl held snug against the edge, as shown, and n tises or tenons can be laid out at will.

Besides being crenalated, these squares h all the advantages of other squares, and are made and pleasant to handle. They are m by the manufacturers, The Peck, Stowe & W cox Co., of Southington, Conn., in polished st copper plated, blued, with enameled white ures, and in nickel plate.

Another combination tool, consisting of slot square and rules, is shown in Fig. 21. I give

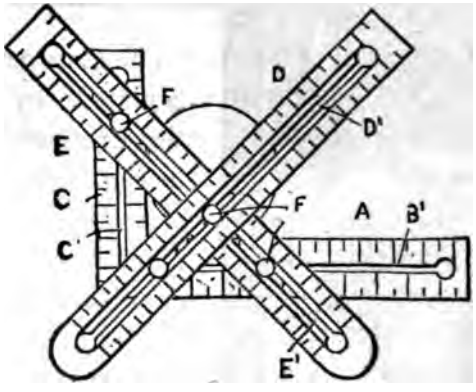

FIG. 21. SQUARE SET FOR MITERS

inventor's description of it, and upon exam tion I have found that with a little study the is capable of performing all that is claimed

it. While I do not recommend this tool as being the best suited to the carpenter's requirements, it may prove a great help to him in solving many problems. Here is what the inventor says: "The invention consists mainly of a square and two slotted straight edges adapted to be fastened upon it by means of bolts. The great utility of this improved instrument will at once be appreciated in the hands of the practical mechanic. The steel square is not like such other mechanical tools as the hammer, saw or plane, which bring into use the strength and motion of the arm. The square on the other hand brings into use the powers of the mind. The carpenter of to-day is an intelligent mechanic, and he requires tools which are up to the times and fully adapted to the work in hand. This tool does not fail to meet with the approval of all who have seen it, and those who use it in their respective trades.

"The instrument enables the mechanic to ascertain the lengths and bevels of all diagonal lines by an improved and ready method without the use of mathematical calculation, such as the lengths and bevels of all kinds of rafters, hips, groins, braces, brackets, purlines, collar-beams and jack rafters, also the bevels and cuts for

hoppers and all the straight lines required in stair-building and handrailing, and the bevels and cuts for polygon miters of any number of sides up to 12.

"With this instrument the carpenter can also measure the width of streams for bridge work, height of buildings, trees or mountains.

"The square can be operated with one rule or two rules, or on squares that are not slotted, by the use of a washer of the same width or diameter as the rule being placed on the opposite side to that of the rule.

"A model of the above instrument may be had, consisting of one square 6x4, rules 1x8, and protractor 2x5, with scales and rules, etc., made from fine white strong cardboard. All the lines are printed with black ink. More knowledge can be derived in one hour by the use of this model than by reading books and drawings for a week."

There was published in connection with this square a little book of directions in which the manner of working the square for the solution of various problems was fully described, but I do not think, in view of the fact that later on I will endeavor to illustrate many of the same problems and solutions, that it is necessary to say

more of this combination tool than to state that

FIG. 22. SET FOR STAIR STRING

Fig. 21 shows the instrument set for miters, Fig. 22 for laying out treads and risers for stairs, and Fig. 23 is arranged for laying out equal spaces either for joists, studding, rafters or any other work requiring equal spacing. The spaces may be any distance within the capacity of the length of the slot in the blade and the projecting edges of the rules.

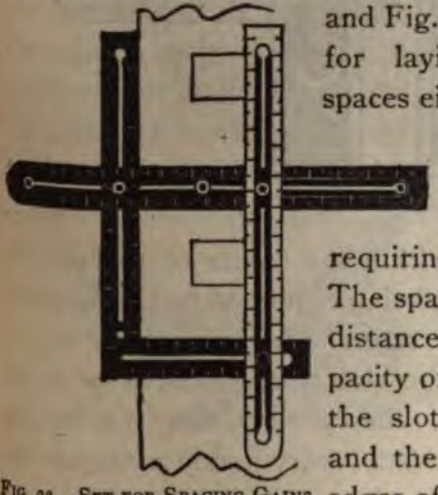

FIG. 23. SET FOR SPACING GAINS

Another class of steel squares which carpenters and joiners and stair-builders are using to some extent may now be discussed.

The illustration shown at Fig. 24 exhibits tw steel try-squares that are adjustable. They a also graduated so that the stock can be set t

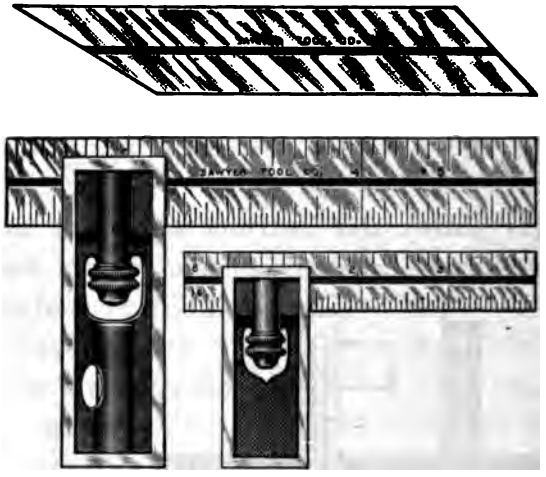

FIG. 24. ADJUSTABLE TRY STEEL SQUARE

any distance within the limits of the square this adjustment being regulated by the loosenin of the thumb screw when the stock can b moved along the slot to any desired point an held there by simply tightening the thum screw. This makes a very handy try-square fc bench purposes when getting out dimensio stuff by hand for fine work, the divisional lin being fine and accurate.

In the stock of the larger squares there is

spirit bulb accurately set, so that the square can, if desired, be used as a level or for a plumb. These squares are supplied with hardened blades. The larger size with the level will often be found convenient. A hardened bevel blade with ends ground to angles of 30° and 45° is furnished when desired. This can be inserted in the mortise made in the stock to receive the blades, which, of course, must be removed to make room for the beveled blade.

These tools are manufactured by the Sawyer Tool Manufacturing Company, Massachusetts, who also manufacture several other kinds of try-squares of a less costly quality. This firm also makes a steel square which the firm calls the "combination set," an illustration of which is

FIG. 25. COMBINATION SQUARE, MITER AND INCLINOMETER

hown at Fig. 25. This square has a blade 24 ıches long, accurately divided in fine grades,

and has a slot running its whole length· shown in the cut, as the reverse side conf us—in which the attachments slide. T attachments are held in place by thumb sc two of them having spirit bulbs in them, sc the square may be used as plumb rule, le inclinometer, as the attachment shown i middle of the square, may be placed at angle as a protractor, on which all the de from 1 to 180 are carefully marked. This with its attachments, may be used for a many purposes in framing and general · The square stock has a miter angle on its edge which will be found handy for layin miters on mouldings when there is not a r box in sight. It will be found very usel cutting trim where the stuff is beaded or mo on the edge. The central attachment fo bevel stock, as it can be set to any bevel, an blade may become the blade of a bev simply loosening the set-screw, adjustin angle and then tightening up again. The attachment is simply a right angle with it sides set at angles of 45° to the edges o blade. The skilled workman will under the use of this at a glance, as its applicati cutting double miters will suggest itself i

diately. Any or all these attachments can be slid off the blade instantly, which gives a fine and correct straight edge and measuring rule. Left with the stock alone it becomes an ordinary try-square or a long miter tool, just as the workman may decide.

These tools are made of the very best materials and the workmanship is, like Caesar's wife, "above suspicion." In the square in my possession the spirit bulbs are placed in position with the greatest of care, the adjustments being as near perfect as possible, and the protractor, under test, is all that can be desired.

Another series of squares made on similar lines, possessing the same qualifications, workmanship and materials, is manufactured by the L. S. Starrett Company, Massachusetts, a firm known the world over for the excellence and

FIG. 26. STARRETT'S CARPENTERS' SQUARE

perfection of their tools. At Fig. 26 I show an illustration of their carpenter's square, which has a movable stock, and may be had with

blades 24 inches long. The stock can be moved or "slid" along the blade to any point, and one side may be used as a square and the other as a miter at the will of the operator. The stock is held in place by the aid of a thumb screw, as seen, and, as the "tit" sliding in the slit is accurately fitted, it is next to impossible for the tool to get "out of truth." These squares are all tested before leaving the works. The stock is fitted up with a spirit level bulb, which is accurately adjusted and tested before being placed on the market. With this bulb the square may at a moment's notice be converted into a level or a plumb rule. The square may be obtained alone, as shown in the illustration, or it may be ordered with attachments, which include center head and bevel protractor or inclinometer, all of which may be added to, or removed from, in a very short time. The instrument, as shown in the illustration, is complete, but the attachments give it a much greater range.

This company also manufacture a square attachment which they call "Starrett's Stair Gauge Fixtures," of which I give an illustration at Fig. 27, which also shows a few of the applications of the device.

A pair of these fixtures can be readily clamped

to a carpenter's steel square to form a gauge for various uses.

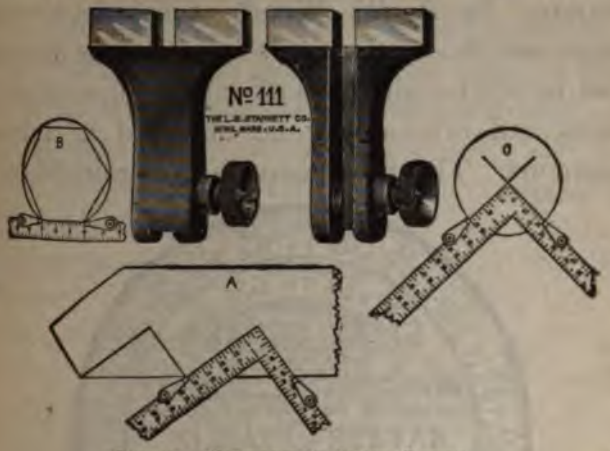

FIG. 27. STARRETT'S STAIR GAUGE

Sketch A shows the gauge as applied for laying out a stair stringer, sketch B laying off hexagon angles, sketch C as used as a center gauge or in quartering a circle.

As a matter of fact this device is intended to take the place of the old-time "fence," of which I will have more to say further on.

STEEL SQUARE TABLES AND RULES

We now enter into another phase of the subject, namely, a discussion of the various schemes and devices invented for the purpose of making the uses and applications of the steel

square easy to understand. One of the best of these is known as "The Key to the Steel Square," by A. W. Woods, which is a very ingenious device for showing how the length and bevels for all kinds of rafters, hips, valleys, jacks and braces may be obtained in a few moments. The instrument is shown in the two

KEY TO THE
STEEL SQUARE
BY A. W. WOODS.
SIDE CUT OF JACK; 12 ON T. COM. R. ON B. CUT ON B.
SIDE CUT OCT. JACK; 5 ON T. COM. R. ON B. CUT ON B.
SIDE CUT OF HIP; 17 ON T. HIP ON B. CUT ON B.
RAFTER TABLE.
SEAT CUT
COM. R. 12
OCT. HIP. 13
HIP OR V. 17
ON TONGUE
ON BLADE
PLUMB CUT 8
LENGTH FOR 1 FT. RUN
14.42
15.26
18.79
COM. RAFTER
OCTAGON HIP
HIP OR VALLEY

FIG. 28. STEEL SQUARE KEY

cuts, Figs. 28 and 29, and the directions for using are given in the following:

KEY TO THE STEEL SQUARE

These directions are published in connection with the framing chart known by the above title. The chart consists of a dial plate 3½x3½ inches square, on either side of which is a revolving

one side giving the lengths and cuts for common rafter, having a rise from 1 to 24 es to the foot, also the corresponding ths and cuts, and bevels for the octagon hip alley, and for the hip or valley resting on a t angled corner, while on the other side is n the seat and plumb cuts for rafters and es having a rise from 1° to 90°. It also s the length of sides and miter cuts for all

KEY TO THE
STEEL SQUARE
BY A.W. WOODS.
TABLE OF TANGENTS.
OUTER FIGURES (IN THE CIRCLES) REPRESENT DEGREE (OF PITCH)
BLADE GIVES PLUMB CUT FROM 1° TO 45°
CHANGING TO THE TONGUE FROM 45° TO 90°
SET NUMBER 12 ON TONGUE.
TANGENT
6.63
ON BLADE.

FIG. 29. STEEL SQUARE KEY

ular polygons, or the framing of timbers at degree, and shows how to apply the steel are to obtain the cuts.

EXPLANATION

he side containing the rafter table is divided

into twenty-four sections, radiating to a common center. These sections represent from 1 to 24 inches rise to the foot in run. The first figures represent the rise, and the three following sets of decimal numbers represent the lengths in inches of the common rafter, octagon hip and the common hip or valley rafter respectively. The heavy-faced fractional numbers designate the pitch or proportion of the rise of the roof to that of the span, while just beneath the fractional numbers is given the same value in decimal fractions to the one-hundredth part of an inch. The latter is placed here for convenience in finding the near equivalent in common fractions for the decimal part of an inch.

The revolving disk contains the title and abbreviated instructions. By turning the disk until the slot rests opposite the pitch desired only the lengths and cuts for that pitch will be exposed, thereby preventing errors.

EXAMPLE: TO FIND THE LENGTHS AND CUTS FOR THE ½ PITCH

Operation.—Turn the disk until the slot is opposite ⅓ and you have as follows: 12 on the tongue and 8 on the blade. The tongue will give the seat cut and the blade the plumb cut for the common rafter.

the corresponding octagon hip and the
on hip, or valley, substitute 13 and 17 on the
: and blade respectively. (Neither are
tely correct, though near enough for all
:al purposes.) The tongue always giving
it cut and the blade the plumb cut. The
s of the rafters for a one-foot run are
to be 14.42, 15.26 and 18.76 for the
on rafter, octagon hip and common hip, or
respectively. Having the lengths given
ne foot in run it is an easy matter to find
ngths of the rafters for any run in either
r inches by multiplying the lengths here
by the number of feet and fraction of a
the run, and point off as many places in
oduct as there are decimal figures used in
lution, and reduce to feet and inches.
onal figures may be avoided in the run by
ng them and finding the length only for
mber of feet, and then from the plumb cut
re square out the amount of the fraction,
will give the point for the proper plumb

ind the common difference in the length
ks multiply the length of the common
(14.42) by the number of inches in the
g, and divide by 12. Thus, if the jacks be

placed 16" on centers, 14.42 × 16 = 230.72 ÷ 12 = 19$\frac{2}{12}$ + inches.

To find the common difference for the octagon jack multiply 14.42 by 2.4, and the product by the spacing, and divide by 12. Thus: 14.42 × 24 = 34.608 × 16 = 553.728 ÷ 12 = 46$\frac{1}{12}$ + inches.

For the Side Cut of the Jack.—Take 12 on the tongue and 14.42 (14$\frac{5}{12}$) on the blade. The blade will give the desired cut.

For the Side Cut of the Octagon Jack.—Take 5 on the tongue (because 5 is practically equal to the side of an octagon when the diameter is one foot) and 14$\frac{5}{12}$ on the blade, the blade giving the cut.

The figures that give the side cut of the jack in either of the above cases will also give the cut across the face of the roof boards to fit in the valley or over the hip. The tongue gives the cut.

For the Side Cut of the Hip or Valley.—Take 17 on the tongue and 18.79 (18$\frac{1}{12}$) on the blade the blade giving the cut.

Backing of the Hip.—Take 17 on the tongue and 8 on the blade. The tongue will give the required bevel. A quicker way, however, is to set off ½ the thickness of the hip along the line of the seat cut (or a line parallel with it), which

will give the gauge point from which to remove the wood to the center of the back of the hip. The backing for the octagon hip is practically one-half of that for a hip resting on a square corner.

REFERRING TO THE TABLE OF TANGENTS

The figures in the two circles represent the degree. Those in the inner circle represent the tangents, and those in the outer represent the cotangents, the sum of the two always equaling 90°.

The set number is in either case 12 on the tongue and tangents on the blade. The blade gives the plumb cut up to 45°, then it reverses to the tongue from 45° to 90°.

EXAMPLE: TO FRAME A ROOF WITH 30° PITCH

Operations.—Turn the slot till it rests opposite 30°.

Common Rafter.—Take 12 on the tongue and 6.93 (6$\frac{1}{8}$) on the blade.

Octagon Hip.—Take 13 on the tongue and 6$\frac{1}{4}$ on the blade.

Hip or Valley.—Take 17 on the tongue and 6$\frac{1}{4}$ on the blade. The tongue in either of the above cases gives the seat cut and the blade the plumb cut.

Side Cut of Jack.—Take 12 on the tongue and the diagonal length from 12 to 6½ taken on the blade. The blade will give the cut.

Side Cut of Octagon Jack.—Take 5 on the tongue and proceed as for the common jack.

Side Cut of Hip or Valley.—Take 17 on the tongue and the length from 17 to 6½ taken on the blade. The blade will give the cut.

If the roof be 60° pitch proceed the same as for the 30° pitch (using the same figures), but the cuts are reversed on the square. However, this only applies to the seat and plumb cuts.

EXAMPLE: TO FIND THE MITER FOR ANY REGULAR POLYGON

Operation.—Divide 180 by the number of sides in the polygon. The quotient will be the degree of the miter.

EXAMPLE: TO FIND THE MITER FOR A NONAGON (9 SIDES)

Operation.—180 ÷ 9 = 20. Turn the slot to 20° and we have 4.37. Then 12 on the tongue and 4.37 (4⅜) on the blade will give the miter, the blade giving the cut. 4.37 is also the length of the sides of the polygon when the inscribed diameter is one foot. If the diameter be 8 feet multiply 4.37 × 8 = 34.96 ÷ 12 = 2′ 10½″. Therefore,

2' 10$\frac{1}{2}$" will be the length to cut the pieces. Only polygons with number of sides that will divide 180 without a remainder are contained in the table, the octagon and heptagon being in this number. Their tangents are 4.97 and 5.78, respectively.

EXAMPLE: TO FRAME TIMBERS AT ANY DEGREE OF PITCH

Frame two pieces at an angle of 110°. It is evident that the miter should stand at half way between the two pieces, or at 55°, and 55° from 90° leaves 35 , and we find the tangent for 35° is .70021, which multiplied by 12 equals 8.40 (8$\frac{13}{32}$"). Therefore, 12 on the tongue and 8$\frac{13}{32}$" on the blade will give the miter, the blade giving the cut.

The reader will notice that the chart only applies to the even pitched roof, or in other words, where the several parts are of the same pitch; and while it may be used for the common rafter in such roofs, it does not apply in such cases to the hip and valley, or the length of their jacks. The side cuts for the jacks, however, may be found by taking the run of the left common rafter on the tongue and the length of the right common rafter on the blade. The blade will give the cut for the right jack; *vice versa* for the left jack.

The foregoing is copyrighted by Mr. Woods, but he has been courteous enough to allow me to use the matter in this work.

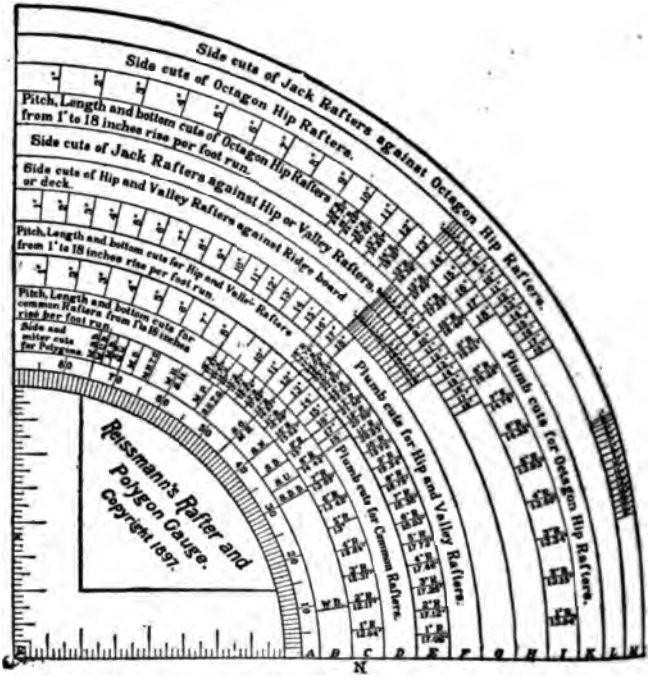
Side cuts of Jack Rafters against Octagon Hip Rafters.
Side cuts of Octagon Hip Rafters.
Pitch, Length and bottom cuts of Octagon Hip Rafters from 1" to 18 inches rise per foot run.
Side cuts of Jack Rafters against Hip or Valley Rafters, or deck.
Side cuts of Hip and Valley Rafters against Ridge board
Pitch, Length and bottom cuts for Hip and Valley Rafters from 1" to 18 inches rise per foot run.
Pitch, Length and bottom cuts for common Rafters from 1" to 18 inches rise per foot run.
Side and miter cuts for Polygons
Reissmann's Rafter and Polygon Gauge. Copyright 1897.
Plumb cuts for Hip and Valley Rafters.
Plumb cuts for Common Rafters.
Plumb cuts for Octagon Hip Rafters.

FIG. 30. REISSMANN'S RAFTER AND POLYGON GAUGE

Another great help to the workman is shown at Fig. 30. This is a rafter and polygon gauge, in which the figures are given for all kinds of cuts in rafters, hips, jacks, valleys for octagons or other polygons by aid of the table and a steel square. This instrument will give the correct

and miter cuts for a pentagon, hexagon, gon, octagon, nonagon, decagon, undeca- and dodecagon; the length of common, valley and octagon hip rafters; the pitch, and side cuts for the above-named s; the side bevel of jack rafters against nd valley rafters and also the side bevel of rafters against octagon hip rafters; the cuts for level planceer, crown moulding, hing and shingles for hip and valley; the es from 1 to 90, and a scale representing 1 to 1 foot. With this gauge 390 cuts and s may be obtained instantly and with te accuracy. A little study and practice of eminently useful article will prove it indis- ible to every mechanic connected with the ing industry.

is instrument is the invention of F. Reiss- , New York, from whom further in- ation may be obtained. The instrument is ed by patents.

obtain any desired angle in the construc- of buildings and roofs apply the tongue of dinary carpenter's sliding T-bevel against dge of gauge marked "N," then move the of bevel so that its outer edge will coin- with the arrow point on gauge marked "O"

and the line from which the angle is to b taken.

This gauge measures 10x13 inches over all and is made up of three-ply veneer, well glue together, and is highly polished, making i impervious to water. It is almost indestructible and will last a lifetime. Full directions for usin the gauge for all purposes are printed on th face of the instrument, so that the directions an the gauge are never apart. I have one of thes gauges before me as I write, and am led, whil explaining it, to indulge a moment in retrospec and wonder how much the mechanics of to-da owe to the men who invent and devise suc instruments as those shown at Figs. 28, 29 an 30. Fifty years ago it was quite difficult t find a man who would undertake the construc tion of a complicated roof. And I have know of buildings having the work suspended fc quite a while, because of no workman presen being able or willing to undertake the puttin on of the roof, and men had to be brought fro a distance to do the work, and these importe men were looked upon as being quite superic beings. Workmen in those days knew nothin of the capabilities of the steel square, indee there were no steel squares as we now kno

them, only iron ones, imported from England or Belgium, and of very inferior manufacture. Now, with the aid of the perfected square, and the treatises thereon, and the instruments provided as above by the ingenious gentlemen named, almost any mechanic—if he have any brains at all—can lay out a roof no matter how difficult it may appear and construct the same in half the time it took our grandfathers to do the work, and the roofs are just as well constructed to-day as roofs were in the olden days. The modern mechanic has much to be thankful for, and he owes to men like Riddell, Reissmann and Woods a monument of gratitude for the efforts they have made in making what was once a very difficult affair, a most simple and easily understood operation.

Fig. 31 shows another very ingenious diagram, which in conjunction with the square, makes the obtaining of the angle-joints for any kind of a polygon quite an easy matter. This diagram requires no explanation, as the direction of the lines shows how the joints are found. The lines are also laid off in degrees, enabling the operator to make use of the lines or angles as degrees and minutes, or as arbitrary lines as he may determine. This diagram is the invention

of A. W. Woods, architect, and is a credit to his ingenuity and mathematical skill.

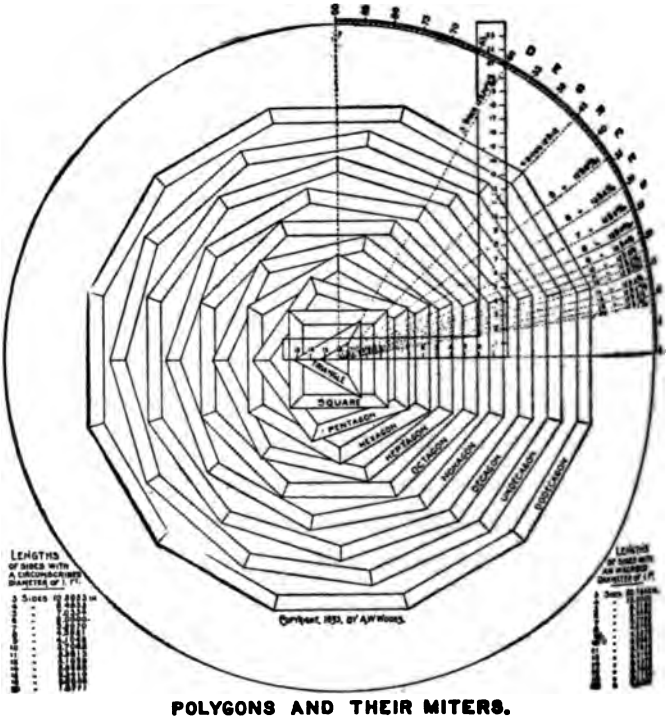

FIG. 31

THE FENCE

The first thing required in connection with the square is a "fence." This is a simple affair and may be of wood or of metal according to the

taste or wealth of the user. This device is a very old one, and has been the cause of considerable controversy as to its origin. In a series of articles I contributed to "The American Builder" in 1875, I illustrated and described this attachment, not claiming it as my own device, but giving it just as I had found workmen making use of it, and I was brought to task concerning it by a man named Joseph R. Gill, who claimed it as his own invention, having employed it, so he stated, in 1844. On this statement I at once wrote a letter to "The American Builder" stating the fact, as I then thought, giving the credit of the invention to Mr. Gill, and this letter was published in the journal in 1878, and brought from several parts of the country a number of protests, declaring that Mr. Gill was very much mistaken if he supposed he was the first originator of the fence.

One person writing from Springfield, Mass., says:

"I have just had brought to my notice an item in your paper, "The American Builder," written by a correspondent named Hodgson, that some man by the name of Gill claims to have invented the little attachment used on the steel square, which he calls a 'fence,' but which is known

down here as a 'guide.' Now, sir, my
was an old framer; he has been dead ov
years, and when a boy I remember of his
a 'guide,' such as your correspondent de
in his letters on 'The Steel Square and Its
I served my time with my father, and ma
of the same scheme long before Mr. Gill
possibly have used it, unless he is a ve
man—for I have entered my fourth score
and I used the square and guide before
fourteen years old. Mind, I do not clai
my father invented the guide, nor do I
where he got the idea from, but I imagine
quite a common thing among carpente
before my father's time.

"Excuse the length of this, but I thou
best to correct an error even if it is a trivi

"Respectfully yours,

"JOHN WILL

"SPRINGFIELD, MASS., Sept. 16, 1878."

Several of these letters were forwarded
by the then editor of "The American Bu
Chas. D. Lakey, Esq., and a few of them a
in my possession, the above being a copy
of them.

I have thought the above necessary b
this Mr. Gill, who was a very eccentri

singular man, published a book in 1892, entitled, "Gill's Detail on the Square," which perhaps never would have been heard of had I not given it some publicity, and in its pages, which abound with eccentricities and fairy-like problems, he *cruelly* accuses me of appropriating his "thunder" and stealing his fence, and devotes nearly two pages of the seven, which go to make up his book, in showing how unjustly he had been treated because of the omission of his name in connection with this fence in the hundreds of thousands of volumes on the steel square bearing my name that have been scattered all over the country during the last twenty-five years.

So much for the history of the fence so far as I know it, and I trust my readers will understand that I do not claim that I originated it. I found it in general use among framers and described it as I found it.

The fence, which is adjustable, is shown at

FIG. 32. DOUBLE SLOTTED FENCE

Fig. 32, and is made from a strip of hardwood about 2 inches wide, 1 ½ inches thick and 2 ½ feet long. A saw kerf, into which the square will

slide, is cut from both ends, leaving about 8 inches of solid wood near the middle. The tool is clamped to the square by means of screws at convenient points as shown. Another style of fence, which is made of a piece of hardwood,

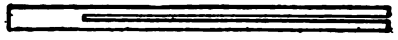

FIG. 33. SINGLE SLOTTED FENCE

has a single slot only as shown in Fig. 33. The square is slipped in and fastened in place by screws similar to the first. An application of the fence and square combined is shown at

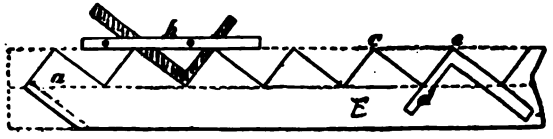

FIG. 34. SHOWING APPLICATION OF SQUARE AND FENCE IN LAYING OUT A STAIR STRING

Fig. 34, where the combination is used as a pitch-board for laying out stair strings. In this example the blade is set off at 10 inches, which makes the tread, and the tongue shows the riser, which is set off at 7 inches. The dotted line, *ca*, shows the edge of the plank from which the string is cut, and *h* shows the fence, *a* shows the bottom tread and riser. In this example the riser shows the same height as the riser above it, namely, 7 inches. This is wrong, as the first

riser should always be cut the *thickness of the tread less* than those above it, as shown by the dotted lines on the bottom of the string, then when the tread is in place it will be the same height from the top of the floor to the top of the first tread, that the top of first tread is to top of second one and so on.

Suppose we wish to lay out a rafter having eight inches rise and twelve inches run. Set the

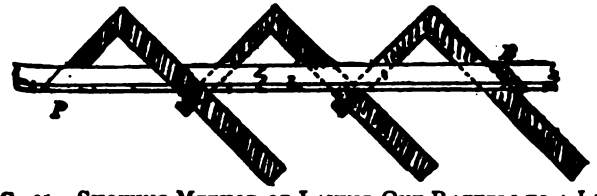

FIG. 35. SHOWING METHOD OF LAYING OUT RAFTERS TO A LINE

fence at the 8" mark on the blade, Fig. 35, and at the 12" mark on the tongue, clamping it to the square with 1¼" screws. Applying the square and fence at the upper end of the rafter we get the plumb-cut P at once. By applying the square as shown twelve times successively the required length of the rafter and foot-cut B is obtained. In this case the twelve applications of the square are made between the points P and B. Run and rise must also be measured between these points. If run is measured from the point B, which will be the outer edge of the

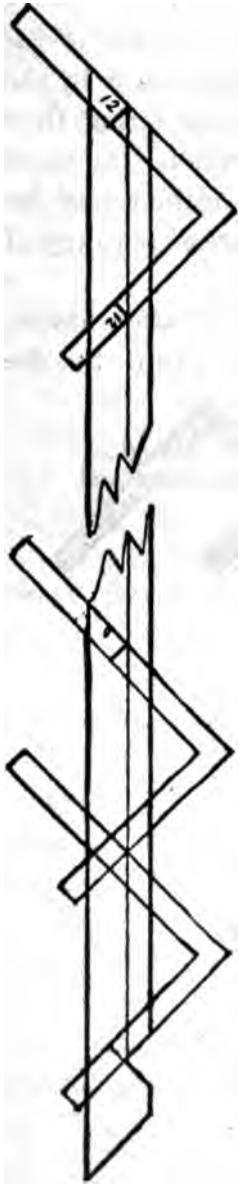

FIG. 36. SHOWING HOW TO LAY OFF A RAFTER WITHOUT MAKING USE OF A FENCE

wall plate, it will be nec
sary to run a gauge l
through B parallel to t
edge of the rafter, and s
tract a distance from t
height of the ridge to g
us the correct rise. T
square must then be appli
to the line L. A rafter
any desired rise and r
may be laid off in this ma
ner by selecting proportic
al parts of the rise and r
for the blade and tongue
the square. For a half-pit
roof use 12 in. on bo
tongue and blade, for
quarter-pitch use 6 in. a
12 in., for a third-pitch u
8 in. and 12 in., etc. T
terms half-pitch, quart
pitch, etc., refer to the heig
of the ridge expressed a
fraction of the span.

The line L is supposed
represent the path of t
fence as it is slid along t

edge of the rafter. This will be explained at greater length in following pages.

At Fig. 36 I show a method of laying out a rafter without making use of a fence. In this case the roof is supposed to be half-pitch, so we take 12 and 12 on the square and apply it to the rafter as many times as there are feet in half the width of the building, which in this case will be 15 feet, as we suppose the building to be 30 feet wide. As the lower end of the rafter is notched to sit on the plate we must gauge off a backing line, as shown, to run into the angle of the notch. This line will be the line on which the gauge points 12 and 12 on the square must start from each time.

Starting from this notch apply the square, keeping the twelve inch mark on both sides of the square carefully on the backing line, and marking off the rafter on the outside edges of the square. Repeat this until you have fifteen spaces marked off, then set back from your last mark half the thickness of the ridge-board, and with the square as before mark off the rafter. This will be the exact length and also the plumb-cut to fit the ridge-board. Or if we take the diagonal of 12 by 12, which is 17, and mark off 15 spaces of 17 in., making the necessary

allowance for the half thickness of the ridge-board, it will amount to the same thing, every 17 in. on the rafter being nearly equal to one foot on the level.

Should the building measure 30 ft. 9 in. in width—the half of which is 15 ft. 4½ in.—we take the fifteen spaces of 12 by 12 and then the 4½ in. on both sides of the square on the backing line as before. This will give us the extra length required. The same rule will apply to any portion of a foot there may be.

A fence, sometimes called a stair gauge, is manufactured of metal by the Cheney & Tower Company, Athol, Mass., which I show at Fig. 37, and is considered about the best thing of the kind. It consists of a piece of polished angle metal, each side being ⅞ inch wide. One side is slotted to accommodate the heads of the set-screws and to allow the slides to be fastened at the desired points. The gauge is fastened to any square, and is useful for laying out stairs, cutting in rafters, cutting bevels or other angles. In marking off stairs with an 8-inch

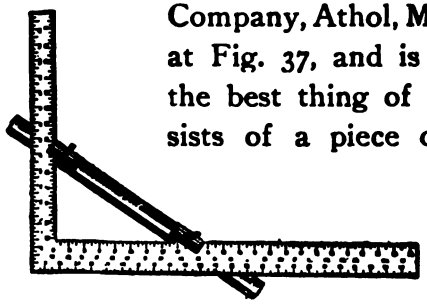

FIG. 37. SHOWING METAL FENCE

rise and an 11¼-inch tread the gauge would be fastened at 8 inches on one end of the square and at 11¼ at the other end. The square would then be laid on the plank with the face of the gauge against its edge and the mark made around the point of the square. This would be repeated until the required number of steps were marked. The gauges are made in two sizes, 18 and 28 inches long. It is stated that mechanics who have used it find it one of the handiest tools in their kits.

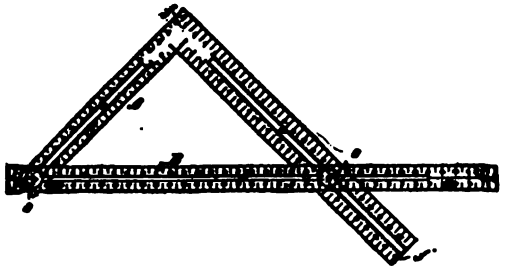

FIG. 38. FENCE AND SLOTTED SQUARE

Another style of fence is shown at Fig. 38 in conjunction with a slotted square. This, perhaps, is the handiest of all the devices for a fence, but it is expensive, and as constructed requires a square with a slot in each arm, and as a rule workmen do not take kindly to squares with slots in them. A shows the square, B the fence, SS set screws to hold the fence in position, and *ff* the points of the square.

The application of the square and fe
bined for laying out a housed string for
shown at Fig
this exam
fence is a
slotted one, a
screws are e
to hold the s
position. Th
seven inches
tread is laid
inches on th
The square
foot of th
shows how t
should be fin
make the fl
the base-boa
this case n
board is req
the square v
justed with
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of the pitch-l
There ar
other applica
the fence in connection with the squar

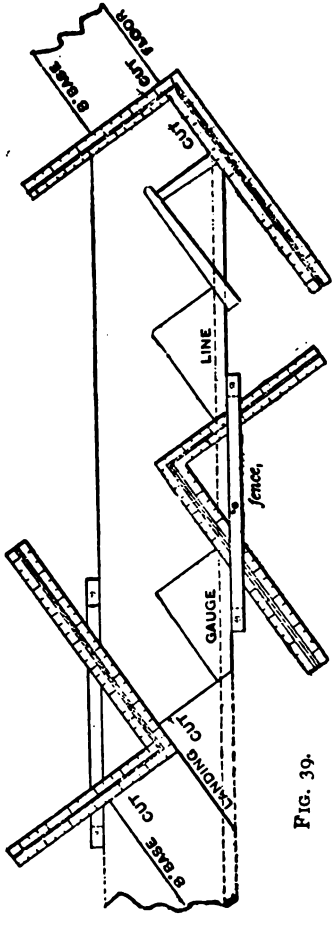


FIG. 39.—SHOWING APPLICATION OF SQUARE AND FENCE IN LAYING OUT A "HOUSED" STRING

may have cause to refer to as I proceed, as it is my desire to present in this work everything I can collect regarding the square that I think will be of service to the workman. Doubtless there will be many descriptions and illustrations some of my readers will have met with before, or which they have been acquainted with for a long time. The great bulk of readers, however, will be new hands, and unacquainted with the use of the square beyond its simple application as a squaring tool, and what may appear to be a useless rule to the expert or old hand will prove a choice tidbit to the beginner and will whet his appetite for further knowledge on the subject. Indeed this book is prepared more particularly for the younger members of the craft, although a majority of the older workers will find much in it that will interest, amuse and instruct.

It will be seen that the fence or guide used in connection with the square is, after all, a very simple matter, and would, no doubt, suggest itself to any clever workman who was laying off rafters with the square, and it is very likely that the fence originated in the minds of many men —Mr. Gill included—but I must confess that it is such a simple matter that it is not worthy of the

attention paid to it or its origin that M
and others have given it.

BRACE RULES

It will now be in order to show how the
can be used for getting the lengths and
for braces of regular and irregular runs.
wish to lay out a brace having a three-f
on both post and beam, the matter i

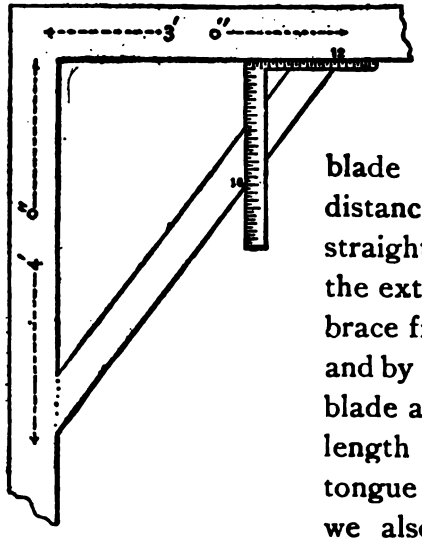


FIG. 40. SHOWING CUTS AND LENGTH OF AN IRREGULAR BRACE

simple, for
take 12 inc
the tongue
inches
blade and transf
distance three tim
straight line and w
the extreme lengt
brace from point t
and by marking al
blade at one end
length and alon
tongue at the oth
we also get the
This is easy and
enough, and with
ther refinements will give the lengths and
exactly for a flat-footed brace. When th

different than the rise, as in the example shown at Fig. 40, the square is applied in a somewhat different manner. Here we have a run of three feet and a rise of four feet. To get the proper length and bevels for a brace to fit in this situation we must use 12 inches on the tongue and 16 inches on the blade, then the bevel of the upper end of the brace will be found along the line of the tongue, and the line of the blade will give the bevel for the foot of the brace. In this case the square is transferred three times, just as though the rise and run were both three feet; the difference being made by dividing the odd foot into three equal parts of 4 inches each and adding one part to the blade, thus making the gauge point on the blade 16 inches instead of 12 inches, which regulates the extra length and the change in bevels. A little study on the part of the reader will reveal to him how the square may be set to gauge points so as to make a brace suitable for any rise and run of any right-angled frame work.

A brace intended for equal run and rise of four feet is shown at Fig. 41. Here we have the fence in use, and the square is shown in all its positions from start to finish in the formation of the brace. The gauge line marked *oooo* is

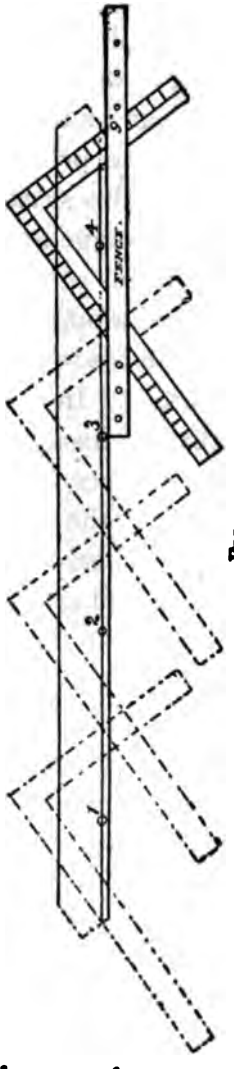


FIG. 41

the line from which the mark
12 and 12 are supposed t
measure, and this whe
squared over as shown leave
a butt, or "heel of the brace
which is to rest on a shoulde
"boxed" in both beam an
post. The dotted lines on th
ends of the brace show th
tenons for which mortises a
made in both post and girt
beam. It must be understoo
of course, that this operatic
is only performed once f
each kind of brace, and th
on a pattern made of son
kindly wood, such as pin
cedar or whitewood. For th
pattern, dress up a piece
the wood to 4 inches wide
the braces are to be made
4x4-inch stuff; if for larg
or smaller stuff then mak
the pattern the width
brace to suit. Have the pa
tern of sufficient length; i
for a 4-foot run and rise it will require to b

ess than 6 feet long. Run a gauge line
-eighths of an inch from the straight or
edge, as shown at oooo, and set the two
:h marks on this line, then screw the fence
on the square with its sliding edge against
:dge of the pattern, and then slide and
as shown four times, when the length
bevels of the brace will be obtained.
de for the tenons beyond the lines shown
ıe square, or for a "flat-foot" brace, saw
imber off on the lines shown on the edge
ıe square. After the pattern is made
ence and square may be laid aside, as
ıattern can be used for any number of
s, and when finished with on one job, may
:ely placed away to use again for the same
and rise" when occasion arises. The
n may be any thickness from half an inch
: inch. The same rules may be observed
king patterns for any regular or irregular
ınd rises.

h regard to the *brace rule* as given on steel
:s, I may say that there is some slight
:nce in the lengths given by different
·s—though nearly all modern makes figure
ce—but this difference is so small that in
vood framing it has no effect. In hard-

wood framing the framer never applies t rules, but gets his lengths with the square fence.

The length of any brace simply represent hypothenuse of a right-angled triangle. To the hypothenuse extract the square root of sum of the square of the perpendicular horizontal runs. For instance, if 6 feet is horizontal run and 8 feet the perpendicul squared equals 36, 8 squared equals 64, 36 64 equals 100, the square root of which i These are the figures generally used squaring the frame of a building or found wall.

If the run is 42 inches, 42 squared is double that amount, both sides being e gives 3528, the square root of which is, in and inches, 4 feet 11.40 inches.

In cutting braces alway allow in length a sixteenth to an eighth of an inch more the exact measurement calls for.

Directly under the half-inch marks on outer edge of the back of the tongue wil noticed two figures, one above the other. T represent the run of the brace, or the le of two sides of a right-angled triangle; figures immediately to the right represent

ngth of the brace or the hypothenuse. For istance, the figures ‡‡ 59.91 show that the run n the post and beam is 36 inches, and the ngth of the brace is 50.91 inches.

Upon some squares will be found brace measrements given where the run is not equal, as ł 30. It will be noticed that the last set of gures are each just three times those mentioned ı the set that are usually used in squaring a uilding. So if the student or mechanic will fix ı his mind the measurements of a few runs, ith the length of braces, he can readily work lmost any length required.

Take a run, for instance, of 9 inches on the eam and 12 inches on the post. The length of race is 15 inches. A run, therefore, of 2, 3, 20, r any other number of times the above figures, ıe length of the brace will bear the same proortion to the run as the multiple used. Thus, you multiply all the figures by 4 you will have 5 and 48 inches for the run, and 60 inches for ıe brace, or to remember still more easily, 3, 4 nd 5 feet, or 6, 8 and 10 feet.

There are other runs that are just as easily xed in the mind. 51-inch run, brace 6 feet, 2 hundredths of an inch; 8 feet, 3-inch run, race 11 feet, 8 inches, etc.

This completes the description of br
on the square, so far, but I will revert
subject again. Every mark, line and fig
been carefully considered, and a full e
tion given of their use and meaning. I hav
more space than was at first intended, c
an anxiety to have every mark thorou
plained, so that even a beginner could
a square and be able to explain to any
use and meaning of every figure. This
the subject has been more for the benef
younger workmen, but I am sure the olc
will appreciate the explanations.

The following brace table has been c
prepared and may be depended upon a
correct measurements:

TABLE

TH OF ON		LENGTH OF BRACE		LENGTH OF RUN				LENGTH OF BRACE	
ft. in.		ft.	in.	ft. in.		ft. in.		ft.	in.
6	=		8.48	4 3	×	4 3	=	6	0.12
9	=		10.81	4 3	×	4 6	=	6	2.27
9	=	1	0.72	4 3	×	4 9	=	6	4.49
1 0	=	1	4.97	4 3	×	5 0	=	6	6.74
1 3	=	1	7.20	4 6	×	4 6	=	6	4.36
1 3	=	1	9.23	4 6	×	4 9	=	6	6.51
1 6	=	1,	11.43	4 6	×	5 0	=	6	8.72
1 6	=	2	1.45	4 9	×	4 9	=	6	8.61
1 9	=	2	3.65	4 9	×	5 0	=	6	10.75
1 9	=	2	5.69	5 0	×	5 0	=	7	0.85
2 0	=	2	7.89	5 3	×	5 3	=	7	5.09
2 0	=	2	9.94	5 6	×	5 6	=	7	9.33
2 3	=	3	0.12	5 9	×	5 9	=	8	1.58
2 6	=	3	2.41	6 0	×	6 0	=	8	5.82
2 6	=	3	4.36	6 3	×	6 3	=	8	10.06
2 6	=	3	6.42	6 6	×	6 6	=	9	2.30
2 9	=	3	8.59	6 9	×	6 9	=	9	6.55
2 9	=	3	10.66	7 0	×	7 0	=	9	10.79
3 0	=	4	0.83	7 3	×	7 3	=	10	3.03
3 0	=	4	2.91	7 6	×	7 6	=	10	7.28
3 3	=	4	5.02	7 9	×	7 9	=	10	11.52
3 6	=	4	7.31	8 0	×	8 0	=	11	3.76
3 9	=	4	9.62	8 3	×	8 3	=	11	8.00
3 3	=	4	7.15	8 6	×	8 6	=	12	0.24
3 6	=	4	9.31	8 9	×	8 9	=	12	4.49
3 9	=	4	11.54	9 0	×	9 0	=	12	8.73
4 0	=	5	1.84	9 6	×	9 6	=	13	5.22
3 6	=	4	11.39	10 0	×	10 0	=	14	1.70
3 9	=	5	1.55	10 6	×	10 6	=	14	10.19
4 0	=	5	3.78	11 0	×	11 0	=	15	6.67
3 9	=	5	3.63	11 6	×	11 6	=	16	3.16
4 0	=	5	5.79	12 0	×	12 0	=	16	11.64
4 0	=	5	7.88	12 6	×	12 6	=	17	8.13
4 3	=	5	10.03	13 0	×	13 0	=	18	4.61
4 6	=	6	0.25	13 6	×	13 6	=	19	1.10
4 9	=	6	2.51	14 0	×	14 0	=	19	9.58
5 0	=	6	4.83						

SOME PRACTICAL EXAMPLES OF THE UCES OF THE SQUARE

The following applications of the square were published by Mr. John O'Connell, of St. Louis, Mo., in the "Scientific American Supplement," September, 1877, along with much other matter concerning the square. While I do not purpose giving all of Mr. O'Connell's paper I think it but fair to my readers to lay before them those portions of it which I think will be interesting and instructive. In connection with this paper it must be understood that the squares in use in 1877 were not figured as squares are to-day, and while the matter given is correct on the whole, there may be some little confusion in the figuring of the lumber rule, but this is not serious.

THE OCTAGONAL SCALE

The octagonal scale is shown by Fig. 41. It is on the opposite side of the tongue. It is used in this way: If you have a stick 10 inches square which you wish to dress up octagonal make a center mark on each face, then with the com-

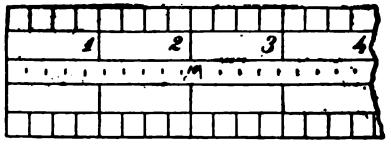


FIG. 41½

passes take ten of the spaces marked by the short cross lines in the middle of the scale, lay off this distance each side of the center lines. Do the same at the other end of the stick and strike a chalk line through these marks. Dress off the corners to these lines, and the stick will be octagonal. If the stick is not straight it must be gauged and not marked with the chalk line. Always take a number of spaces equal to the square width of the octagon in inches. This scale can be used for large octagons by doubling or trebling the measurements.

To Find the Number of Inches to Take on Blade and Tongue for a Given Rise and Run of a Brace. —Divide the shorter rise or run of the brace or rafter into a number of equal parts, each part not to exceed the length of the tongue of the square. Divide the longer rise or run into the same number of parts, each part not to exceed the length of the blade, and if it does, divide the shorter rise or run into a greater number of parts. Example: A rafter with a run of 10 feet and a rise of 6, 12 inches on tongue and 20 on blade taken six times will give the length and bevels; or 15 and 9, taken eight times. When a brace or rafter is too long to be conveniently worked in this way take a half or a third of both

rise and run, and take two or three times the answer.

When you find the number of inches to take on the square lay the latter on a straight edge or line and find what diagonal length it gives This multiplied by the number of parts in rise or run gives the whole length of brace.

To Find a Circle Equal in Area to Two or More Circles, Fig. 42.—Let A be ¾ inches or feet in diameter, and B 1¼. Measure across from the ¾ inch on one arm of the square to the 1¼ inch on the other This distance is the diameter of the required circle C. If there were three circles we should set the diameter of the third on the tongue and that of C on the blade, and the diagonal distance between these points would be the diameter of a circle equal to the three and so on for any number. This applies to squares also. By this simple rule we can find the size of one pipe equal to two or more, and square spouts in like manner, for grain elevators, for flour mills, or similar work. Similar figures of all kinds may be worked by this method—

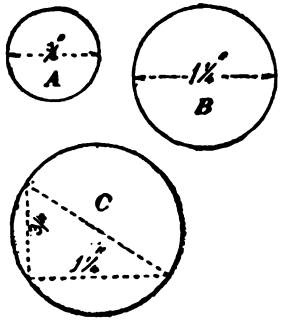


FIG. 42

triangles, rectangles, hexagons, octagons, etc.—taking similar dimensions only, that is, if the shortest side of one triangle is taken, the shortest side of the other must be taken also, and the answer gives the shortest side of the required triangle.

Three Points Not in a Straight Line Being Given to Find the Center of a Circle Which Will Pass through Them, Fig. 43.—Let 1, 2 and 3 be the points. Connect them by straight lines, and square from half the distance between them as at *d* and *e*. The intersection of these perpendiculars is the center.

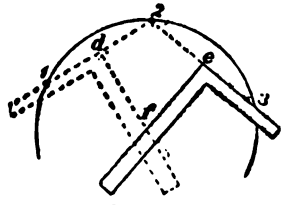


FIG. 43

To Find the Center of a Circle with a Square, Fig. 44.—Lay the square on the circle with the corner at the circumference. Mark where outer edge of tongue and blade cut the circle, and draw a line connecting these points. This line is always a diameter, and by drawing in like manner a diameter in another direction the intersection of the two gives the center.

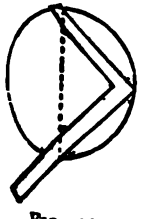


FIG. 44

To Find the Side of a Square of Half the Area of a Given Square, Fig. 45.—Let G be the given

square; half its diagonal gives the side of the smaller square. A square constructed on the diagonal of G would contain double the area.

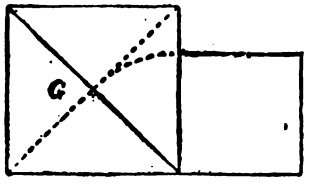


FIG. 45

To Lay off Angles of 60° and 30°.—Mark any number of inches, say 14, on an indefinite line. Place the blade against one extremity of this distance and the 7-inch mark of the tongue at the other. The tongue then forms an angle of 60° with the indefinite line, and the blade an angle of 30°.

To Lay Off an Angle of 45°.—A diagonal line connecting equal numbers on both arms of the square forms angles of 45° with the arms.

The Hypothenuse and One Side of a Right-Angled Triangle Being Given, to Find the Other, Two Sides Being Given to Find the Hypothenuse.—Find in a manner similar to the rule for obtaining the length of a brace. For example, let the hypothenuse be 15 inches and one side 7½ inches to find the other. Dividing these dimensions by three we have 5 inches for the side and 2½ inches for the hypothenuse. Mark off the 5 inches on the edge of a board or a straight line, as in Fig. 46. Lay the square with the 12-inch mark at *b*,

and move the blade till it touches the other 5-inch mark at *a*. From *a* to *c* is found the length, which multiplied by 3 gives the hypothenuse.

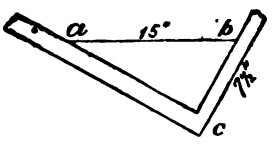


FIG. 46

To Lay Off an Octagon in a Square, Fig. 47.—Draw the diagonals *e* and *f*. Mark off the distance from the corner to the center *g* on all sides, measuring from the corners. The resulting marks give the corners of the octagon.

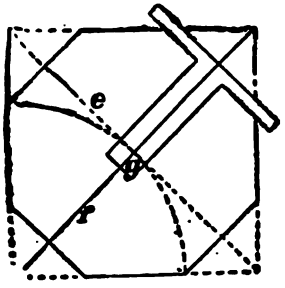


FIG. 47

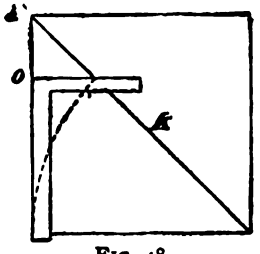


FIG. 48

Fig. 48. Another method is to measure off the side of the square on its diagonal *k*. Square from a side to the point thus found on the diagonal, and *no* is the distance to be gauged from each corner to mark the corners of the octagon.

To Lay Off an Octagon on a Given Side, Fig. 49.—Prolong the given side *ab* and lay off an angle

of 45° at both *a* and *b*. The lines, 1, 2, are squared up from the given side, also lines 3 and 4. By applying the square to the other lines we get the remaining sides.

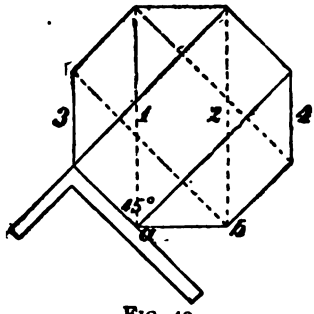


FIG. 49

To Make a Square Stick Octagonal, Fig. 50.—Lay the square or a two-foot rule diagonally across the stick so as to measure two feet on it, letting the

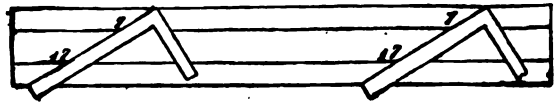


FIG. 50

corners on the same side of the blade or rule touch the edges of the stick. Make marks at the 7-inch and the 17-inch marks. Measure thus at each end of the stick. Lines struck through these points show what is to come off to make it octagonal.

To Find the Side of an Octagon When the Side of the Square Is Given.—Multiply the side of the square by 5 and divide by 12. The quotient is the side of the inscribed octagon.

When the Side of the Octagon Is Given, to Find the Square Width.—Suppose the side of the

octagon is to be 16 feet, take half this, or 96 inches, for the square, 16 inches on both tongue and blade taken six times, giving 11 feet 3¾ inches, which being doubled and added to the side of the octagon gives the square width.

Given the Square Width, to Find the Diagonal, Fig. 51.—Take half the square width and half the side on the square, or proportional parts, double what is found from these and the result is the diagonal.

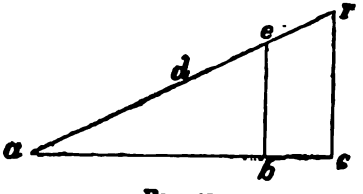


FIG. 51

To Find the Bevels and Width of Sides and Ends of a Square Hopper, Fig. 52.—The large square represents the upper edges of the hopper, and the small one the lower edges, or base. The width of the sides and ends is found in this way: Take the run, *ab*, on the tongue and the perpendicular height, *ad*, on the blade. It is thus found in the same manner as the length of a brace. To find the cut for a butt joint take width of side on blade and half the length of the

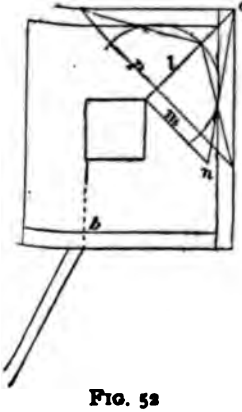


FIG. 52

base on tongue; the latter gives the cut. For a miter joint take width of side on blade and perpendicular height on tongue; the latter gives the cut.

For the cut across the sides of the boards take the run *ab* on the tongue and the width of side on blade; the tongue gives the cut. The inside corners of the side and ends are longer than the outside, so if a hopper is to be a certain size the lengths of ends and sides are to be measured on the inside edge of each piece and the bevels struck across the edges to these marks. This is only in case of butt joints. Of course if the hopper is to be square the thickness of the sides must be taken from the ends.

If the top and bottom edges are to be horizontal the bevel is thus found: Take the perpendicular height of hopper on the blade and the run on the tongue, the latter gives both cuts. A hopper can be made by the above method by getting the outside dimensions at top and bottom and the perpendicular height.

In large hoppers pieces are put down along the corners to strengthen them. The length and the bevel to fit the corners are thus found. Suppose the top of hopper is 8 feet and the bottom 18 inches square. Find the diagonals of

ıch, subtract the one from the other and half ıe remainder is the run for the corner piece. 'rom the length of this run, *l*, and the rise, *ab*, ve find the length of the corner piece. To find the bevel or backing take on the blade the length of the corner piece and on the tongue the rise; the latter gives the bevel. Another method is to draw the line *l* to represent the seat of the corner piece, set off square with this the line *m* of the same length as the run *ab*. Then draw *no*, which is the length of the corner ›iece. To find the backing draw a line, *p*, any- 'here across *l* at right angles therewith, and at s intersection with line *l* strike a circle tangent › *no*. From the point of intersection of the cir- e with *l*, draw lines to the extremities of *p*. The ıgle made by these lines is the bevel or backing.

Another method generally employed for ıding the bevels of hoppers is to bevel the top ıd bottom edges of the sides and ends to the ngle they are to stand at, then to lay a bevel set o a miter, or angle of 45°, on the beveled edge, and that will lay off a miter joint, while a try-square will lay off a butt joint. An angle of 45° will miter only those boxes with sides which are vertical and square with each other.

When the sides and ends of a rectangular box

or hopper are of the same width, that is, when sides and ends slope at equal angles, the bevels, either butt or miter, are found as for square hoppers.

When a hopper has the sides and ends of different widths, that is, when sides and ends stand at different angles, both having the same rise, find the cuts for each from its respective rise, run and width.

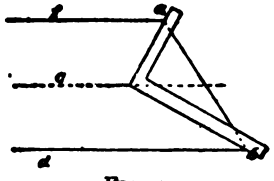


FIG. 53

Fig. 53. To bisect the angles *a* and *b* simultaneously with the square: Draw the center line *c*, place the corner of the square on this line and move blade and tongue to the angles, then draw the bisecting lines. This method is possible only when lines *d* and *f* are parallel.

Fig. 54 shows how the angles for an octagon plan may be obtained. *a b* is a line of diameter, and *a c* the line of angle required.

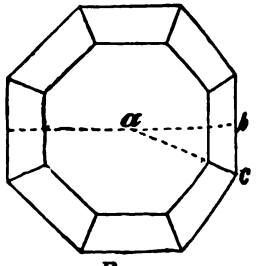


FIG. 54

ROOFING

Fig. 55. A hip roof with two corners out of square is given as an example, the dimensions of

:h are: Width, 15 feet; rise of roof, 5 feet;

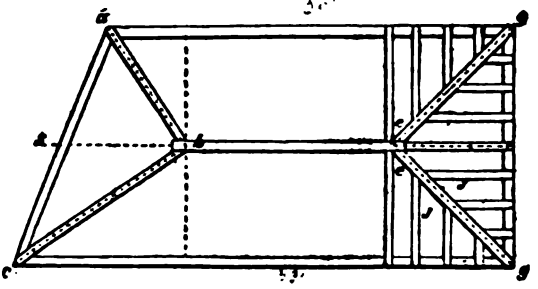


FIG. 55

th, 30 feet on the shorter side; 33 feet on the
'er. The timbers, *ab*, *cb*, *cg*, *eg*, are the hip
:rs; JJ the jack rafters. The seats of each
rafter should form a square, so that each
of jack rafters, JJ for instance, may be cut
ıual length.

'ngths and Bevels of Hip Rafters.—We will
consider those on the square end of the
. In order to find their length it is first neces-
to obtain their run, which is found as
'ws: Take half the width of building on
blade and tongue, whence is obtained the
th of seat from *g* to *e* at the intersection of
dotted lines. By similar use of the square
length with the rise of roof gives the length
he hip rafter. The lengths of all the rafters
ıld be measured along the middle, as the
ed lines show. This is the full length; half

the thickness of the ridge-pole is to be taken off measured square back from the bevel.

The bevel of the upper end of a hip rafter i called the down bevel. It is always square wit the lower end bevel, hence these bevels ar found by the parts taken on the square to fin the lengths of the hip rafters. Another metho is to take 17 inches on the blade and the numbe of inches of rise to the foot, that is, the rise i inches divided by half the width of roof in fe on the tongue. The tongue gives the dow bevel, the blade the lower end bevel. Th reason for the foregoing is that when the hi rafters are square with each other the seat c the hip is the diagonal of a square whose side i half the width of building. The diagonal of square with a 12-inch side is nearly 17 inches So if the rise of roof in 1 foot is 6 inches the ris of hip rafter will be that only in 17 inches. Th directions here given assume that the hip rafte abut the ridge-pole at right angles, but as th ground plan of the roof shows that they meet a an acute angle another bevel must also be con sidered, called the side bevel of the hip rafters Were there no slope to the roof the bevel wher they meet the ridge-pole would be an angle o 45°, as the hips would be square with each

When a pitch or slope is given the hips
: from the right angle and, therefore, the
evels are always less than 45°. Take the
ı of hip on the blade, and its run on the
ɛ; the blade gives the cut.

king of the Hip Rafters.—The backs of the
.fters must be beveled to lie even with the
ı of the roof. This bevel must slope from
iddle toward either side. It is found by
; the length of hip on blade and the rise ot
of on tongue. The latter gives the bevel.

Find the Lengths of the Jack Rafters.—Sup-
:here are to be four between the corner
ıe first common rafter; then there are five
ı, which, by dividing 7 feet 6 inches by 5,
foot 6 inches, from center to center of
The rise of roof also divided by 5 gives
rise for the shortest rafter. The run is
: 6 inches, as both rise and run are given
:ngth down and lower bevels are found
rom. The next jack has double the rise,
nd length of the first; the following one
times, and the fourth four times. All the
ırements are to proceed on or from the
e lines of the jacks.

: side bevel of all the jack rafters is
ıed by taking the length of a common

rafter on the blade and its run on the tongue; the bevel on the blade gives the result.

Let us now consider the end of the building out of square. Fig. 55 illustrates the method of laying down the seats of the hips. To find the length of these hips the lengths of the seats must be got by taking half the width of building on blade and the distance from the end of the dotted line crossing the roof to the corner on the tongue. The length of the seat so obtained taken on the square, with the rise of the roof, gives the length of the respective hip rafter.

The down and lower end bevels are found as in the previous hip rafters. To obtain each side bevel add the distance from the dotted line to the corner and the gain of the hip rafter; take the sum on the blade and half the width of building on the tongue; the latter gives the cut.

The lengths, etc., of the jack rafters on the side are determined as at the square end of the roof; the side bevel being found by taking the length of a common rafter on the blade, and the distance from the dotted line to corner on the tongue, the latter showing the bevel.

The Lengths of Jack Rafters on the End.—Assuming there are to be four jacks between the corner and the center included, half the length of the

end of the roof must be divided by 5. One side of the roof being 3 feet longer than the other, we place 3 feet on tongue and 15 feet—the width of building—on the blade, and thus obtain the distance from corner to corner on the end of the roof. Half this divided by 5 gives the distance of the jacks apart. The distance, from where the middle lines of the hips meet in the middle point of the end of the roof, is also to be divided by 5, the quotient giving the run of the shortest rafter. The rise is the same as for the jacks on the square end.

These rules give the full length of rafters, so that when hips come against a ridge-pole or jacks against a hip half the thickness of pole or hip, squared back from their down bevels, must be taken off.

Side bevels of these jacks are obtained by adding the distance from the dotted line to the corner to the gain of a common rafter in running that distance; take this on the blade and half the width of building on the tongue. The blade gives the bevel.

OCTAGONAL AND HEXAGONAL ROOFS

Fig. 56 represents an octagonal roof. In its construction the suggestions on octagons, pre-

viously made, must be referred to. The length of hips is found as usual from rise and run, the run being half the diagonal of the octagon. Cut the first pair full length to butt against each other, the next pair are to be set up at right angles to these, and each is to be cut shorter than the first pair by half the thickness of first pair measured square back from the down bevel.

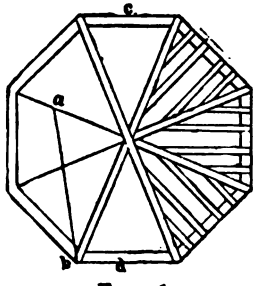


FIG. 56

The third and fourth pairs are to be cut shorter than the first by half the diagonal of a square whose side is the thickness of the first rafter. If the thickness of the first pair is 2 inches then the third and fourth pairs are shortened by $1\frac{1}{16}$, as $2\frac{1}{16}$ is the diagonal of a square whose side is 2.

The first and second pairs have no side bevels; the side bevels of the third and fourth run back on both sides from the middle of the rafter. Find this bevel by taking the original length of rafter on the blade and its run on the tongue when the blade shows the cut. The backing of the hips is obtained by taking $\frac{1}{12}$ of the rise on the tongue and the length of hip on blade; the

ıtter giving the cut, for the side of an octagon
ıy its square width.

Half the square width is the run of the middle
ıck rafter, from which and the rise we get its
ıngth. From the length deduct the same
mount as from the third and fourth pairs of
ips. If there are to be two jacks between the
ıiddle one and the corner we divide the length
f side into three parts, also the rise, whence are
btained, as before, the distance of rafters apart
nd the rise of shortest jack. Divide half the
ıuare width of octagon by three to find the run
f shortest jack. Just as the square is laid on to
nd the length of a jack it gives the down and
ıwer end bevels, while the side bevel is
ɔtained by taking length of middle jack on
ade and half one side of the octagon on the
ngue; the blade giving the cut.

A HEXAGONAL ROOF

The side of a hexagon equals the radius of
e circumscribing circle. The square width, or
ıothem, is determined from one side and a
ıgonal of the hexagon.

The first pair of hips are set up as in the
:agonal roof. The second and third pairs
ve a side bevel. To find this take half the

side of the hexagon on the tongue, and half the square width added to the gain of the hip rafter in running that distance on the blade. The tongue gives the cut. Strike the bevel across the rafter. Now the second and third pairs are to be measured back shorter than the first pair on their middle lines, just half the length of this bevel. The third pair has the bevel cut on both sides from the center. The backing of the hips is found by taking $\frac{1}{12}$ the rise of roof on the tongue, and the length of hip on blade; the latter gives the cut. The side of a hexagon is $\frac{1}{12}$ its square width or apothem. The lengths and bevels of the jack rafters are found as in octagonal roofs.

TRUSSES

Fig. 57, *a* is the straining beam, *b* the brace, *t* the tie-beam. Generally the brace has about one-third the length of tie-beam for a run. From the rise and run find the length and lower end bevel of the brace. After making the lower end bevel on the stick add to it just what is cut out of the tie-beam. The bevel of the upper end of

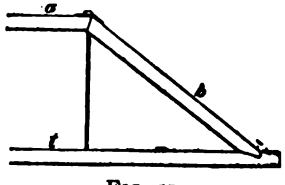


FIG. 57

the brace where it butts against the straining beam is found in the following manner: Take the length of the brace, or a proportional part, and mark it on the edge of a board; take half the rise of the brace on the tongue, lay it to one of these marks on the board, and move the blade till it touches the other mark on board. A line drawn along the tongue gives the bevel for both brace and straining beam. The angle made between brace and straining beam is thus bisected. Lay off the measurements from the outside of the timbers. Put a bolt where shown with a washer under the head to fit the angle of straining beam and brace.

PLAIN STAIRS

See Fig. 34. First determine the height from the top of the floor on which the stairs are to be placed to the top of the floor above, also the run of the stairs. It is necessary to plumb down from the top to get the run or horizontal distance correct. The stringers for stairs are cut top and bottom, like a brace of same rise and run, of course measuring along the inner dotted line as you would measure a brace if the point were to be cut off and let into the post or beam.

Suppose the vertical height to be 10 feet

4 inches, and the rise for each step is required to be about 8 inches; divide the height in inches by 8 to obtain the number of steps. The quotient is 15½. As it is not advisable to have a half step make the number of steps 16, and dividing the total height in inches by 16 we obtain 7¾, the rise in inches of every riser or step. Suppose the run of the stairs is 10 feet 5 inches; divide this distance in inches by the number of steps, which is one less than the number of risers, as the upper floor forms a step to the last riser. The quotient, 8⅓ inches, is the net width of each step; to this there being generally added 1½ inches or so for nosing or projection.

If it is not desired to plane up the edge of the stringer strike the chalk line, *ab*, about the proper distance from the edge, and lay the square on this mark, as at *d*, taking the width of step on one arm and the rise of step on the other. If the edge of the board is dressed straight the square may be laid on as at *h*; a piece of board with a slot sawed through edgewise, as shown by Fig. 32 or 33, when slipped on the square and fastened with screws, making a convenient contrivance for laying out stringers. Generally a piece of thin board is cut out in the

form *cde* with a piece nailed to the edge *c* for a guide. The bottom riser must be made less in height than the others by the thickness of the step. For instance, if the steps are 1½ inches thick, the bottom riser should be 7¾ inches less 1½ inches, or 6¼ inches in height. It is sometimes inconvenient to put a support under a long stair. In that case the triangular piece, *cde*, should not be cut out, but a groove made of same form, with a width equal to the thickness of the step and a depth of about half an inch. When the steps are well fitted into these grooves, and ⅝ inch bolts, with nuts, are run through across the stringers at about every five feet in length and passing close under the steps; the stairs are made very rigid when the bolts are well tightened.

HEXAGONAL AND OCTAGONAL BOXES OR HOPPERS

The cuts for the edges of the pieces of a hexagonal hopper are found by subtracting the width of one piece at the bottom, viz., the width of same at top, and taking the remainder on the tongue and depth of side on blade. The tongue gives the cut. For the cut on the face of the sides take $\frac{1}{7}$ of the rise on the tongue and the depth of side on the blade. The tongue gives

the cut. The bevel for the top and bottom edges is found by taking the rise on the blade, and the run on the tongue; the latter gives the cut.

To find the cut of an octagonal hopper for the face of the board and also the edge subtract the rise from the width of side; take the remainder on the tongue, and width of side on blade; the tongue gives the cut. The edge of the stuff is to be square when applying the bevel. The bevel for the top and bottom edges of the sides are found by taking the rise on the blade, and the run on the tongue; the latter giving the cut. This makes the edges horizontal. The edges are not to be bevelled till the four sides are cut.

CONVEYORS

Let us assume a conveyor in a flour mill or elevator to have the following dimensions: Diameter of shaft, 5 inches; length, 14 feet; pitch of flights or screw, 7 inches. Next cut a piece of stiff paper of form of Fig. 58. The length of this pattern is equal to the circumference of the shaft, 5x3.1416, or about 15.71 inches. The vertical side of the triangle

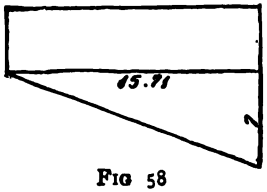


FIG 58

on the pattern is the pitch of the conveyor, ches. The hypothenuse of this triangle is gth of the spiral for one round. Lay off the 1 lines on both sides of the paper. Draw on the shaft parallel to its axis. Lay even iis line the 7-inch side of the pattern trian- nd the pattern around the shaft and draw urse of the spiral along the hypothenuse; ue the spiral by shifting the pattern es further on. To find the whole length spiral we first determine how many times ngth of shaft contains the pitch; the nt is 24. This number multiplied by the of the hypothenuse of the pattern is the ngth of spiral.

e shaft were octagonal but with the same we divide the pitch by the number of sides, gives ⅞ inch for the pitch on one side. a short piece of board as wide as the ter of the shaft, and taking ⅞ inch, or a le thereof, on the blade, and the width of ide of the shaft, or the multiple thereof, on the , place the blade even with wer edge of the board at g. 59, and draw the diag- c. Cut off the end of the board through

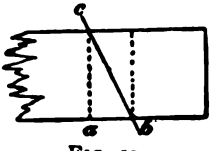


FIG. 59

this diagonal, tack a strip on the lower edge as guide to rest against the side of the shaft. Th pattern will now mark off the spiral, wheth right-handed or left, on every side successively

SAWING TIMBER

Fig. 60 shows how to find the largest rectang lar stick that can be cut from round log. Divide the diameter into three equal parts. Square o from these divisions by 2, to t circle representing the log a connect the points *a*, *b*, *c*, *d*.

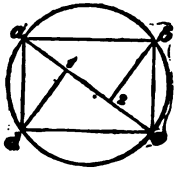


FIG. 60

SCALES

Fig. 61 shows another use for the square. If person is drawing a machine on a scale of 1½ inches to the foot he may simply lay a common rule, *e*, under the square, touching the 12-inch mark on the blade and the 1½-inch mark c the tongue; he then possesses a contrivance b which he may easily reduce from one scale t the other. For instance, if a piece of stic 2¾ inches square is to go into the constructio the draftsman finds the 9¼-inch mark on th blade, that is, 2¾ inches back from the 12-inc mark, and measures square out to the rule, as a

FIG. 61

d. This distance is the reduced section of the stick. A straight mark drawn on a table or a drawing board serves as well as a rule.

TO TEST A SQUARE

The square may be quickly tested by laying it on a wide board, placing the blade parallel to one edge, which must be planed perfectly straight, and drawing a fine line along the tongue. The square is then turned over so as to rest in a reversed position on the opposite side of the line just drawn. If the square now exactly coincides with the line and the board-edge, it is a perfect right angle. A great recommendation of this method is that an inaccuracy of the scale is doubled by the reversing and so made more apparent. If the square is not true it should be set in a vise and draw filed.

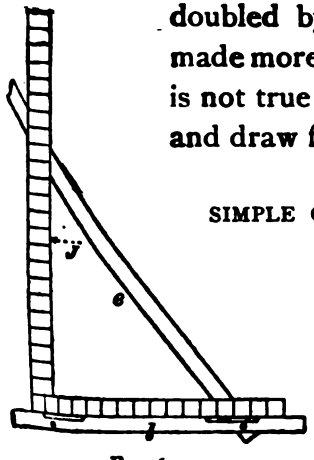


FIG. 62

SIMPLE CALCULATING MACHINE

Fig. 62 shows the application of a long bevel to a square by which some calculations can be made with greater ease and quickness than

by the usual arithmetical process. The larges size of carpenter's bevel square placed under th framing square will answer in nearly every case or any mechanic can make the bevel for himself with blades of steel obtained at a hardwar store. The edge of each blade should be mad perfectly straight and the edge of *l* should b filed down in several places to see the blade when placed under the square. If blade *e* wer placed on the square it covers up the figures o the latter. The two blades should be fastened together by a thumb screw. There should b three holes in *l*, one near each end and one i the middle, and a notch filed by each hole, s that the blade *e* may be shifted when necessary.

These contributions to the literature of the steel square by Mr. O'Connell, while not altogether new when written, have done much toward popularizing the steel square, and have been the means of "drawing out" many good things on the subject from workmen all over the world where the English language is spoken, and they have been quoted and requoted in thousands of instances during the past twenty-five years.

Not only in the United States, Canada, and Australia is a knowledge of the capabilities o

the steel square becoming more diffused and generally understood among workmen, but also in conservative England, where some three or four works have recently been written on the subject, among which I may mention "Practical Roofing Bevels," specially prepared for the "Iron Square," by E. F. Bockham; "Roofing by the Iron Square," by Frank Nicholls; "The Use of the Steel Square for Obtaining Cuts in Carpentry," by Henry Parker.

In the introduction the author of the last named work says: "The square referred to in this work is what is generally known as the 'American Steel Square,' one side being 2 feet long and 2 inches wide, the other varies in length in different squares from 16 inches to 18 inches and 1½ inches wide; the long side is called the blade, the shorter side the tongue, the outer corner of the square is called the heel. On one side on outer edge of square the inches are divided into eight parts, the other side on the outer edge the inches are divided into twelve parts, the side with the inches divided into twelve parts is the side that should be used for finding lengths and bevels, as each inch represents a foot, this scale being most convenient."

This is a fairly correct description of *some*

makes of American Steel Squares, but does n by any means cover the whole ground. Furth on I will give some examples from these work which I am sure will both interest and instru my readers.

Besides the works named, there have bee many articles of more or less value regardin the square and its uses in the English trad papers, in which the writers have evinced a ver fair knowledge of the tool and its application The manner of using the square for the solutio of some of the every-day problems is sometime different from that employed in America, bu results are about the same.

The following article and illustrations, whic are taken from "The Illustrated Carpenter an Builder," a very useful journal published i London, England, will give the reader som idea of how steel square matters are treated b practical men in the old country. In describin the square the writer starts off by saying: Th square is divided on one side into 1 inch, ½ incl ¼ inch, ⅛ inch, and on one side into $\frac{1}{12}$ incl $\frac{1}{12}$ inch and $\frac{1}{24}$ inch. It has also a board measur stamped on one side of the blade, which can b easily understood, and will be often found quit useful. The more expensive ones will have

onal scale at the junction of the blade and ue, which will be found handy when you are ting to take off hundredths of an inch; but the every-day carpenter the ordinary subdi- ons will be found sufficient. There will also diagonal scale on one side of the tongue; two figures placed over each other represent

FIG. 63

the two sides of the square; the figures to the right the hypothenuse, or the exact length of a brace required to touch the measurements given.

Let us take a few examples of using the steel square and plainly show its uses and advantages.

We have to cut a brace to support a beam or bracket. (Fig. 63 shows the square.) We wish it to run to a point 16 inches from the inside of the beam and 21 inches

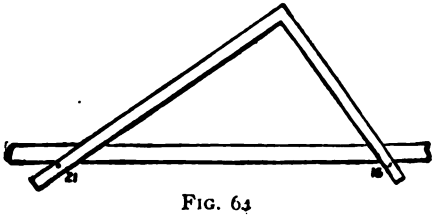


FIG. 64

the post or jamb. We apply the square

thus (Fig. 64): Place the corresponding figures 21 on the blade and 16 on the tongue just touching the edge of the brace piece, mark by both blade and tongue and you have the length and bevels to fit. Fig. 65 shows the brace in position and the square laid on the angle. This shows the workman that the square simply represents the angle into which the brace has to fit. Now this rule follows likewise right through; you make the square represent the angle you have to fit. Sometimes you have a chance to place the brace in position and mark it.

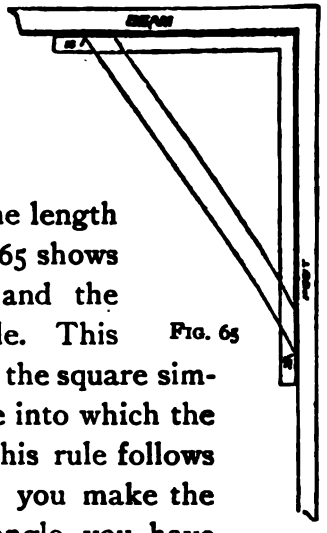


FIG. 65

We now have to fit a similar brace touching a point 2 feet 10 inches on the beam and 3 feet 8 inches down the post, with the ends toed-in ½ inch to prevent its slipping away. We now take 22 inches on the blade and 17 inches on the tongue and apply it to the brace piece as before, repeating the operation, as Fig. 66, which will give the proper

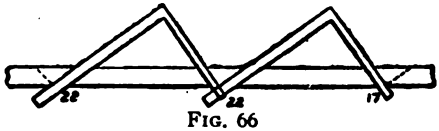


FIG. 66

engtth of the brace. Now square out from the bevel given and measure off on this line ½ inch, now draw line touching the inside edge of the first bevel, and you then have the desired cut.

Fig. 67 shows the brace in position and the square laid on, showing the manner the square is applied when the length is out of the scope of once applying the square and still not long enough to obtain correctly in the manner I am about to show in getting at the length of rafters, although the length and bevel of any rafter can be got in this manner by dividing the rise and run by a number, viz., 10 feet run, 8 feet rise, divided by 6 equals 20 inches and 16 inches; apply square number of times as divisor 6. But great care must be taken to keep the square exactly on the mark made in the previous application, otherwise the rafter will be too long or too short, as the case may be. Therefore, I have always found the following method the best, besides being much quicker for obtaining the lengths and bevels of rafters. Our first roof will consist of rafters with a collar joist nailed across from

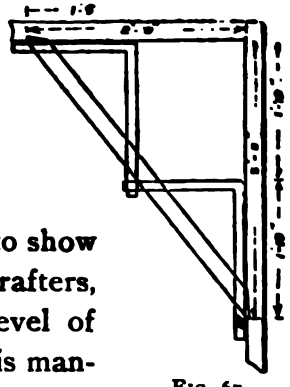


FIG. 67

one to the other at the ceiling line to prevent sagging in the middle, and to act as ceiling joist at the same time. This building will be 22 feet wide, and as we have to consider only half the width, each set of rafters running to the center will be 11 feet, the rise will be 9 inches to the foot, or 8 feet 3 inches to top of ridge-pole.

We now consider the 1-inch divisions on the square as feet and the subdivisions twelfths or inches; we take a straight-edge, or any board with a nicely pointed edge and lay the square on same with the 11-inch mark on the blade and the $8\frac{3}{4}$ inch on the tongue coinciding with the edge of the board. Now take a fine pencil, or better still, a knife, and mark by these on edge of the board the distance between these points $13\frac{9}{12}$ inches, which equals 13 feet 9 inches, which is near enough for all practical purposes. Now take rafter piece, using the 11-inch and $8\frac{3}{4}$ inch marks, bevel at foot by the 11-inch mark, measure off 13 feet 9 inches. Now mark the cut at the ridge by the

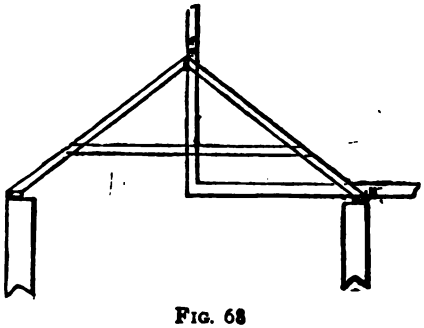


FIG. 68

½-inch mark and measure back from this mark alf the thickness of the ridge. This is length. ig. 68 shows section of roof with the square laid n. To get the bevel of collar joist take the run n the blade 11 inches, and the rise on the tongue ⅜ inches. The blade gives the cut. Supposing he ends of the building have to be hipped in, to et the length and bevels of the hips, etc., pro-eed as follows:

The run of a hip rafter is the diagonal of half he width of building, so we take 11 inches on oth blade and tongue and lay on the straight-dge. This gives us the run of the hip. We ake this measurement on the blade and the

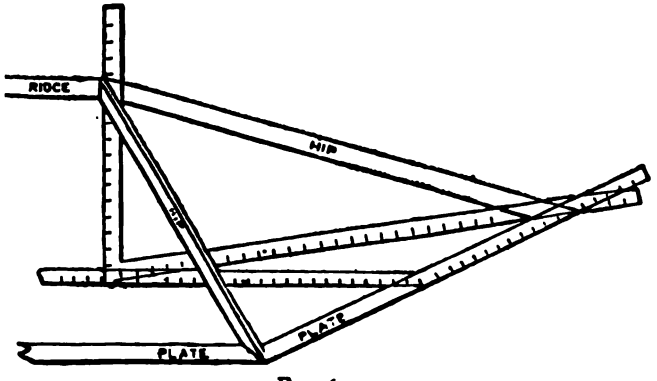


FIG. 69

se 8⅞ inches on the tongue. This gives us the oper length of hip, and these figures the ridge

and plate cuts. For the side bevel, to ridge-pole take the length of the hip blade and the run of same on the tong blade gives the cut. Now as to the jack their lengths can be obtained in the fo manner: Divide the length of the c rafter by the number of openings betw last common rafter and the corner of th ing, and you have the length of the jack, viz., placing the rafters 12 inches on you get eleven openings, so divide 9 inches by 11 you get 1 foot 3 inches. T jack will be twice this length, the thir times and so on. Lay off these measu up the center of the back of jacks and half the thickness. Hip: For the bev hip take the length in common rafters

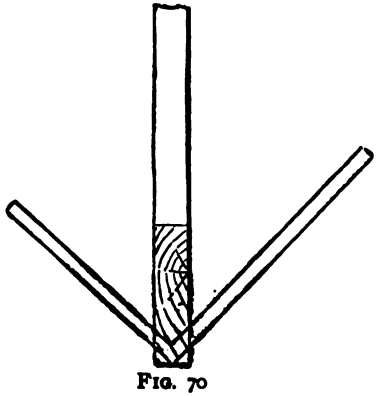


FIG. 70

blade 13 feet and its run 1 tongue; the gives the bev To find th ing of hip t length of hip blade and its the tongue, t gives the b

y the angle of the square on the foot of hip here it fits the plate, taking care that it is ex-:tly true from each corner, mark by and trans-:r them up the sides and you have its correct :vel. (Figs. 69 and 70.)

Fig. 71 is a roof having three gables, each being a different pitch, the two valleys being unequal as regards run. The ridge is 8 feet above the level or plate. Proceed as follows: The rafters for the front

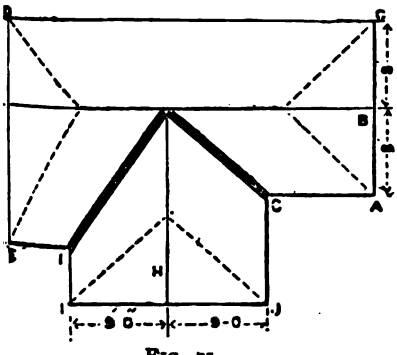


FIG. 71

de of left gable, E, we will consider first. ake the run 13 on the blade and 8 on the se of the tongue, measure across with your foot rule (or lay the square to a straight-lge) and you get 15¼, equal to 15 feet 3 inches, hich is the length. Take 13 on the blade, on the tongue; this gives the plumb and vel cuts. All the other common rafters will : found in the same manner, viz., at AC and D ke 8, and 8 at IJ, take 9 and 8 to get the valley , take 13 inches on blade, the run of the

common rafter on left gable, 9 inches on the tongue, the run of common rafter on front gable, measure across and you have 15⅛, which is, practically speaking, 15 feet 10 inches. This is the run. You now take this on the blade, and the rise, 8, on the tongue, measure across and you get 17¾, which we will call 17 feet 9 inches, the length of the valley. Deduct the diagonal of half the thickness of the ridge, e.g., if the ridge is 2 inches measure across from 1 to 1 on the square and deduct from the total length. The 15 feet 10 inches and the 8 gives the plumb and bevel cuts, the bevels to fit the ridge on the back of valley. Take the length of common rafter on front side, 15¼ on the blade, and the run of the common rafter on front gable, 9 feet, on the tongue, which is the distance it is carried to the right to strike the ridge H; the tongue gives the cut for main ridge, and the blade the cut for ridge H. Now as to the jack rafter on the front side of left gable, we divide the length of the common rafter, 15 feet 3 inches, by the number of openings, as previously shown, which gives us the length of the shortest jack, etc. The bevel across the back will be found by taking the length of common rafter, 15¼ inches, on the blade, and the run of the common rafter

on the opposite side of the valley, 9 inches, on the tongue. The blade gives the cut. The down bevel will be the same cut as the ordinary rafters at the ridge. The other jacks will be found in like manner for the other pitches. Hence the rule to find the bevel across the back of jack rafters when the whole of the roof is the same pitch. The length of common rafter on blade, its run on tongue; blade gives the bevel.

When the hip or valley runs between two different pitches take the length of the common rafter on the side you are working on the blade, and the run of the common rafter on the opposite side of the hip or valley on the tongue. Blade gives the cut. The same rule applies to valley as to hip, as a valley, properly speaking, is an inverted hip.

The main thing in framing a roof by the square is to understand the manner in which the square represents the building. But in looking at Fig. 68 you can see at a glance why it should give the correct length and bevels of an ordinary rafter. Likewise at Fig. 69 you make the blade of the square represent half the width of building and the tongue as well. If your hip runs the same from the end as it does from the side, take the diagonal of this on the blade, and the rise on

the tongue, and you have the length and bevels of it.

The whole thing boiled down presents itself in a very few simple facts, as any practical reader will acknowledge after reading carefully.

We now have a step-ladder to make to reach a landing 8 feet high, and to slope to a convenient point 4 feet 6 inches back. Now, as the square can be manipulated much easier when you are using figures some distance down the blade and tongue and also greater accuracy can be insured in marking a bevel, we take 16 on the blade, 9 on the tongue, and exact proportion to the above, e.g., the quantity doubled. Take your sides and lay the figures to the front edge. The 9 gives you the bevel at floor and bevel of treads. Supposing we give each step a rise of 8 inches, we shall need 11 in the flight, the landing making the necessary 12 inches. We mark floor bevel, and before moving the square make a mark on the side opposite the 8 inches on the blade, as that represents the perpendicular rise; we then repeat this operation eleven times, the last time drawing a line down after the blade; this gives the cut that fits to the landing joist or wall. (Fig. 72.)

It is advisable, when you are using the same

level or figures repeatedly, as in this case, to make a couple of thin strips, say 1½ inches by ⅝ inch, and about 2 feet 8 inches long, run in a screw about 4 inches from each end and insert the square between; set it to figures required and screw up together. You then have a guide which insures your using the same figures each time you apply it. A piece of stock, 1¾ inches by 1¼ inches, with a saw kerf run down about 1 foot from each end, is better still, with two screws to tighten. (Fig. 73.)

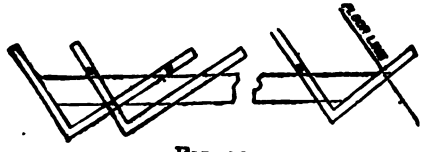


FIG. 72

FIG. 73

There is no roofing bevel but what can be easily and expeditiously found with the steel square, amongst other things finding the bevel at the intersection of any form of polygon, miter and butt joint of hoppers, setting out staircases, finding the area of circles, the diameter being given, etc., and dozens of other problems in mathematics, geometry, etc. There are several books published, I believe, in America on this matter, and during my sojourn in that country I hardly ever saw a carpenter's "kit" that did not

My connection with a number of build
technical journals as editor and contribu
placed me in touch with a number of
workmen who have made a specialty of s
the steel square and its uses, and these
men have never been backward in per
me to make use of such of their suggesti
thought of sufficient importance to lay
my readers.

Among these I may mention D. L. St
Indianapolis, Ind.; Wm. E. Hill, Terre
Ind., and many others, besides the ger
named in the preface of this volume, a
following practical examples are a few o
submitted to me, and which have appe
print in various places. The greater nu
these examples are the work of Messrs. St
and Woods, and their good value will be
ciated after the reader has studied them

other device, but will always be in quest so long as there are mechanics whose daily work requires them to make quick application of mathematical rules. It may be improved from time to time, and made so as to meet special wants better than now, but it is doubtful if much more can be done to it so as to make it more acceptable to the general workman. It has been used since the very beginning of the mechanical trades, and is likely to continue through all the ages.

It is the simplest of tools, and may be described as the mechanical embodiment of a right angle. It must necessarily have some breadth in order to give the tool necessary stability, and, therefore, as the embodiment of a right angle it is of a form to give us both the exterior and interior shape. The blade of the square is made a little wider than the tongue, more for convenience, I think, than for any other reason, for I have seen squares somewhat old, to be sure, and made long before the tools which are now in most common use were sent out from the factory, of which the blade and tongue were approximately of the same width.

The blade of the square, as commonly constructed, is 2 feet, or 24 inches long, and the

tongue somewhat less. I have seen squares of which the tongue and blade were of equal lengths, and also those, the blades of which were considerably longer than those of the square of present make, and still others of which the tongues were considerably shorter than is now the rule. But this is long ago. The most commonly accepted dimensions for a carpenter's square at the present time are, blade 24 inches long, tongue 18 inches long, blade 2 inches wide and tongue 1½ inches wide. This gives for inside measurements blade, 22½ inches and tongue 16 inches.

I have described the square as the embodiment of a right angle. If the square is not a right angle, or to use common terms, if the tool is "out of square," that is, if it is in the least inaccurate, its usefulness is destroyed. When the square is inaccurate instead of solving intricate geometrical problems correctly it becomes a snare and a delusion, leading to false results and misfits in general. It is somewhat remarkable how few workmen test their squares. I am disposed to believe from long experience that comparatively few mechanics who buy steel squares are cognizant of the possible defects that the tool may have and of the tests which

may be applied for the purpose of demonstrating its accuracy. Before proceeding further, therefore, in the discussion of the use of this instrument let us give brief attention to some of the simple methods that may be employed for determining the accuracy of the tool. By way of making practical application of these tests I suggest that at the next dinner hour the reader borrow from his fellow carpenters as many squares as may be convenient, and apply to them more or less of the tests which follow, merely for the purpose of practice, and at the same time to show to what extent the squares in use are correct.

Fig. 74 shows a very common method of testing the exterior angle of a steel square. Two squares are placed against each other and a straight-edge, or against the blade of a third square. If the edges of the

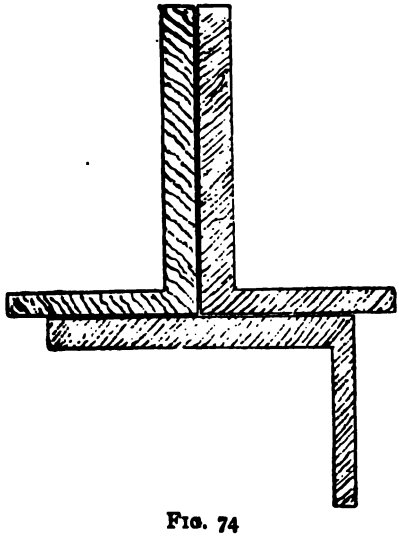


FIG. 74

squares exactly coincide throughout the s
may be considered correct.

Suppose, however, that there is a discr
shown by this test, and that as the two s
are placed in the general position, shown
illustration, they part at the heel, while to
at the ends of the blades, or touching
heel that they part at the ends of the
This evidently shows that one of the squ
inaccurate, or possibly that both are inac
How is the inaccuracy to be located? T
squares may be placed face to face, wi

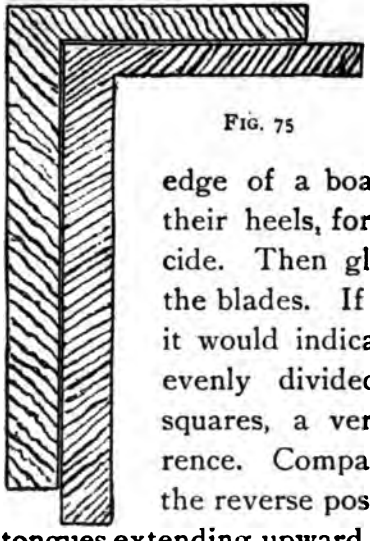


FIG. 75

blades upwar
an even surfa
the face of th
square or the
edge of a board, and so he
their heels, for example, shal
cide. Then glance at the e
the blades. If they exactly c
it would indicate that the e
evenly divided between th
squares, a very improbable
rence. Compare the two squ
the reverse position, that is, w
tongues extending upward. Then apply t
shown in Fig. 75, and finally that shown in

By trying the squares one inside of the other, as shown in Fig. 75, the exterior angle is compared with the interior angle. If the edges throughout fit together tightly, first using one square inside and then the other, it is almost conclusive evidence that both the squares are accurate.

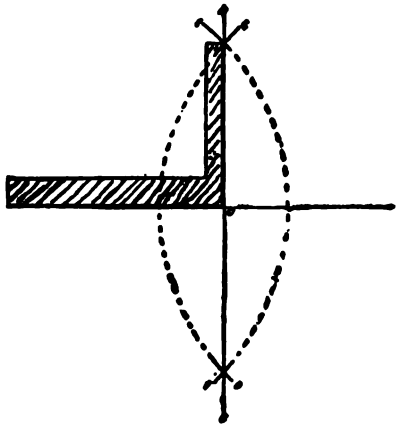


FIG. 76

By tests of the kinds just described among several squares, the mechanic will soon perceive from the several ascertained results that one or the other of the several squares that he is handling is more accurate than all the others, if not absolutely accurate. There still remains the need of a test, however, to prove the absolute accuracy of the particular square which he believes to be about right. On a drafting table, or a smooth board, let him next perform the following experiment, which is one of the several that might be mentioned in this connection: Draw a straight line, AB, say three feet

in length, as shown in Fig. 76. This m
done by a straight-edge. Use a hard
sharpened to a chisel point. With the
passes, using A and B as centers, and v
radius longer than one-half of AB strik
arcs CD and EF. Then with the straigh
draw a straight line, GH, through the int
tion of the arcs. If the work is accurately
the resulting angles AOH, HOB, BOG, and
will be right angles. Lay the square
tested onto one of these angles, as shown
illustration, and with a chisel-pointed pencil
along the blade and along the tongue.
lines thus drawn exactly coincide with tho
drawn it is satisfactory proof that the squ
accurate, and in the same way the squar
be placed against one or the other of these
angles in a way to test its interior angle.

The method shown in Fig. 76 anticipat
use of another tool besides the square in m
the test. A right angle, however, may be
for the purpose described by a method
uses only the square, and which does not re
the services of any other tool, or what
same thing. consider the tool itself to b
figure drawn, and then measure for the pu
of determining the accuracy of the figure.

Various writers have discussed the properties of the right-angled triangle, but we all know that a square erected on a hypothenuse of a right-angled triangle is equal to the sum of the squares erected on the base and perpendicular. This is a well-known mathematical truth, and it may be applied in the tests we are making. Those carpenters who have had occasion to lay out the foundations of houses are well acquainted with the old rule frequently known as "the 6, 8 and 10," which depends upon the relationship of the squares of the perpendicular and the base to the square of the hypothenuse. Thus the square of 6 is 36, the square of 8 is 64. The sum of 36 and 64 is 100. And the square of 10 is 100. Now let us make application of this rule to test the steel square.

For the sake of accuracy we want to take figures which are as large as possible, so as to reduce the possible error in measurement to the smallest possible dimensions. Let us take for dimensions 9, 12 and 15 inches. That these will serve is easily demonstrated. The square of 9 is 81. The square of 12 is 144. The sum of these squares is 225, and the square of 15 is 225. Therefore, if the tool that we are testing shows a dimension of exactly 15 inches measured from 9 on the outside of the tongue to 12 on the out-

side of the blade, as shown in Fig. 77, it proof that the square is correct.

It may be somewhat difficult to make a measurement of this kind on the instrument itself, with sufficient accuracy to be beyond dispute. I suggest, therefore, that the square be laid flat upon an even surface, like a drawing table, and that

FIG. 77

with a chisel-pointed pencil lines be scribe the tongue and along the blade. Mar rately the distance of 9 inches from the l the tongue, and 12 inches from the heel al blade. Then measure diagonally and se distance is exactly 15 inches.

In what has preceded there has been gestion that the error due to lack of preci measurement is diminished if the figur increased in size. If the size of the d table permits, therefore, extend the line along the tongue of the square to Extend that drawn along the blade to In doing this care must be taken that th thus extended are fair to the tool under ination, for if they are not drawn in a

strictly coincide with the edges of the square then the test is of no avail. Then measure from the ends of these lines, that is, from a point 3 feet from the heel up the tongue to a point 4 feet from the heel along the blade. If this diagonal distance is exactly 5 feet it will show that the angle represented by the heel of the square, as I have described it, is a right angle, and that, therefore, the test is accurate.

Now let us next examine a little more carefully the relationship of the square to frequently required lines. It is a common thing among carpenters to use 12 of the blade and 12 of the tongue for a right angle or square miter. Why are these figures employed, or to put the question otherwise, how is it determined that 12 and 12 are the proper figures? Perhaps the question can be made still clearer by another illustration. It is common to say that 12 of the blade and 5 of the tongue is correct for the octagon miter. How is this determined? In Fig. 78 there is shown a quarter circle, XG, described from the center, C. Along the horizontal line, AB, the blade of the square is laid with 12 of the blade against the center C, from which the quadrant was struck. Now if we divide this quadrant into halves, thus establish-

ing the point E, and if from E we drawn a line

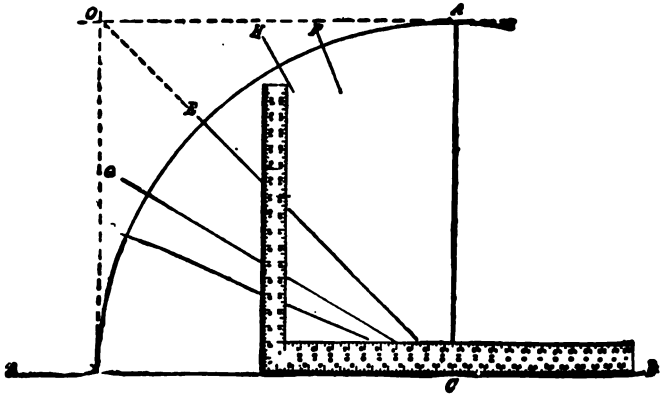


FIG. 78

to the center C, which is 12 of the blade, it will be found that it cuts also 12 of the tongue. If we complete the figure by erecting a perpendicular line from the point X, and intersecting it with a horizontal line from G, thus establishing the point O, it becomes very evident that CE is the miter line of a square.

If we bisect XE, thus establishing the point D, and by the conditions existing setting off in the quadrant a space equal to one-quarter of its extent, and if from D we draw a line to the center, C, corresponding, as already mentioned, with 12 on the blade, we shall find that this line (DC) cuts the tongue on the point 5 (very

rly, the exact figures being 4$\frac{11}{16}$ inches). The DC, as above explained, bisects the eighth circle. In other words, it is the line for an gon miter, and, therefore, we say that for an gon miter we take 12 on the blade and 5 on tongue.

/ dividing the quadrant into three equal s, as shown by XG, GH and HG, we obtain drawing GC the line corresponding to the agon miter. This, it will be observed, cuts the gue of the square at 7 (very nearly, the exact es being 6$\frac{11}{16}$ inches), and, therefore, we say exagon miters we take 12 of the blade and the tongue.

he question sometimes arises, can the square employed to describe a circle? While the are may be used for describing a circle of any meter, providing the capacity of the square is exceeded, still those who attempt to per- the work will very likely conclude before are through that other means are more factory for regular use.

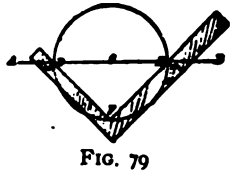


FIG. 79

way to proceed is indica- in Fig. 79. Let it be re- ed to describe a circle, the meter of which is equal to

Drive pins or nails at these points and

place the square as shown in the sketch. Place a pencil in the interior angle of the square, as shown at F. Then gradually shift the square so that the pencil will move in the direction of D, always being careful to keep the inside of the blade and inside of the tongue in contact with the pins or nails, E, D. After having described the arc from F to D reverse the direction, describing the arc from F to E. Then turn the square over and by similar means complete the other half of the circle.

"There are still other methods of testing a square," says "Parallelogram" in *Carpenter*, from whose articles I have drawn freely, and I

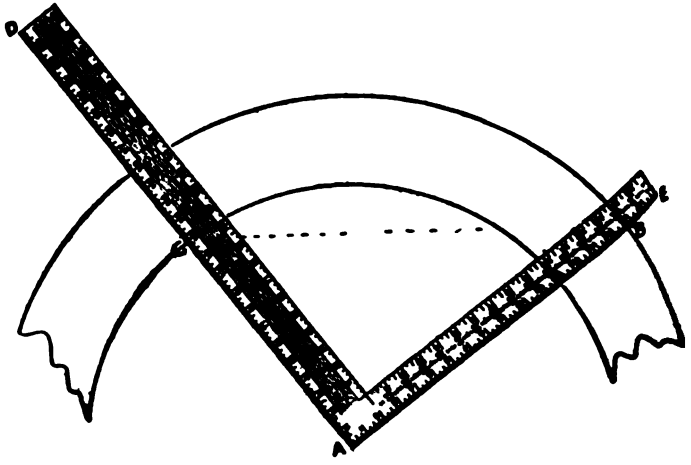


Fig. 80

propose submitting one here. "With an accurate right angle drawn upon a board or otherwise indicated, it is a comparatively simple matter to measure the square by it.

"Referring to Fig. 80 establish the center A at any convenient point. Then with the compasses set to 12 inches and to 16 inches respectively, strike the arcs as shown, producing them until they cover a little more than a quarter circle. Establish the point B wherever convenient on the outer arc, and with the compasses spread to 20 inches and one point in B cut the inner arc, thereby establishing the point C. Through A and B draw the line AE, as shown. Through A and C draw the line AD, as shown. Then DAE will be a right angle, and the square may be tested by laying it on as shown in the sketch."

The same results will be obtained if instead of using 12 and 16 for radii, as above described, we employ 6 and 8, and instead of using 20 for the distance from B to C we use 10. This may suggest to some of my readers that the rule here shown is only an application of that which is very commonly employed among builders in laying out foundations, and which is known as the old "rule of 6, 8 and 10." A little examina-

tion of the diagram will show that this supposi tion is entirely correct. The rule, as commonl described by carpenters, for squaring the corne of a building is something as follows: From th given corner measure along the line in on direction 6 feet, and in the other direction 8 fee Then lay a pole across the angle and move on or the other of the lines until the diagonal mea urement is exactly 10 feet. Of course this rul is based upon the principle that the hypothenus of a right-angled triangle is equal to the squa root of the sum of the squares of the two side Thus the square of 6 is 36, and the square of 8 64. The sum of the squares is 100, and th square root of 100 is 10.

Greater accuracy is secured by extendin these measurements and taking larger number which have the same relationship to each othe Therefore, in the diagram here shown we hav taken 12, 16 and 20. It works out, however, jus the same way. The square of 12 is 144, and th square of 16 is 256. The sum of these tw squares is 400, and the square root of 400 is 2 which is the length of the hypothenuse. Th method, however, that we have taken of drawin a diagram corresponding to these condition is a little different from that which is usuall

employed. We have taken two radii—12 and 16 inches respectively—and with them have struck portions of circles from a given center. Then we have measured from a fixed point in the larger of the two circles to a point in the smaller circle, a distance that is equal to the length of the required hypothenuse. Next we have drawn through these points respectively to the center, A, producing the lines DA and EA, as above mentioned. It is virtually the builders' rule for squaring a foundation worked backwards. It has certain advantages following upon the use of arcs of circles in place of the measuring pole.

It frequently happens in various kinds of work that carpenters require a right angle, the arms of which are very much longer than the squares with which their tool chests are provided. For example, they may want for a certain purpose a right-angled template, the arms of which are 6 to 8 feet in length. In building such a template it is much better to establish the angle by the method here described than to attempt to work by the ordinary tool.

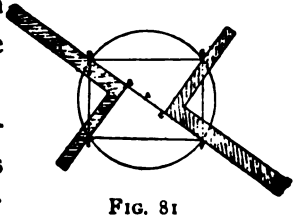


FIG. 81

In the other diagram presented herewith, Fig. 81, is shown a handy method for

determining the dimensions of the largest rectangle that can be drawn in a given circle. A practical application of the rule is to determine the dimensions of the largest timber other than square that could be cut from a given log. Through the center A of the circle draw any diameter, as DF. Divide this diameter into three equal parts, as shown by FC, CD and BD. Place the square as shown in the diagram with the blade against the diameter FD, and the heel against the point C. Draw the line CG, producing it until it cuts the circle at the point G. Reverse the square, as shown, and with the blade still against the diameter, and the heel brought to the point B draw the line BE, producing it until it cuts the circumference at E. Connect E, D and F, G. Also draw GD and FE. Then EDGF will be the dimension of the largest rectangle that can be drawn in the circle, or as above mentioned, the size of the largest stick of timber other than square that can be cut from the log represented by the circle.

The two diagrams, Figs. 82 and 83, when well understood will be found very useful and may be applied in hundreds of occasions in the daily routine of the workman.

Fig. 82 relates to roof pitches, and indicates

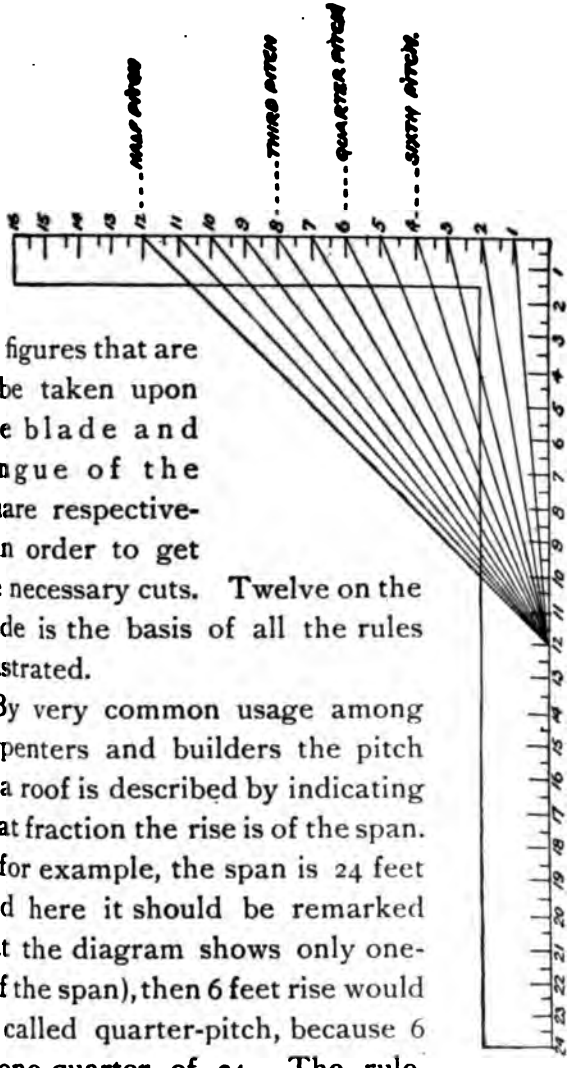


FIG. 82

the figures that are to be taken upon the blade and tongue of the square respectively in order to get the necessary cuts. Twelve on the blade is the basis of all the rules illustrated.

By very common usage among carpenters and builders the pitch of a roof is described by indicating what fraction the rise is of the span. If, for example, the span is 24 feet (and here it should be remarked that the diagram shows only one-half the span), then 6 feet rise would be called quarter-pitch, because 6 is one-quarter of 24. The rule,

somewhat arbitrarily expressed, that is applicable in such cases in roof framing, where the roof is one-quarter pitch, is as follows: Use 12 of the blade and 6 of the tongue. For other pitches use the figures appropriate thereto in the same general manner.

The diagram indicates the figures for sixth-pitch, quarter-pitch, third-pitch and half-pitch. The first three of these are in very common use, although the latter is somewhat exceptional.

It will take but a moment's reflection upon the part of a practical man, with this diagram before him, to perceive that no changes are necessary in the rule where the span is more or less than 24 feet. The cuts are the same for quarter-pitch, irrespective of the actual dimensions of the building. The square in all such cases is used on the basis of similar triangles. The broad rule is simply this: To construct with the square such a triangle as will proportionately and correctly represent the full size. The blade becomes the base, the tongue the altitude or rise, while the hypothenuse that results represents the rafter. The necessary cuts are shown by the tongue and blade respectively.

In Fig. 83 is indicated the relationship of certain divisions of the circle to different figures

on the square. Or to express it a little differ-

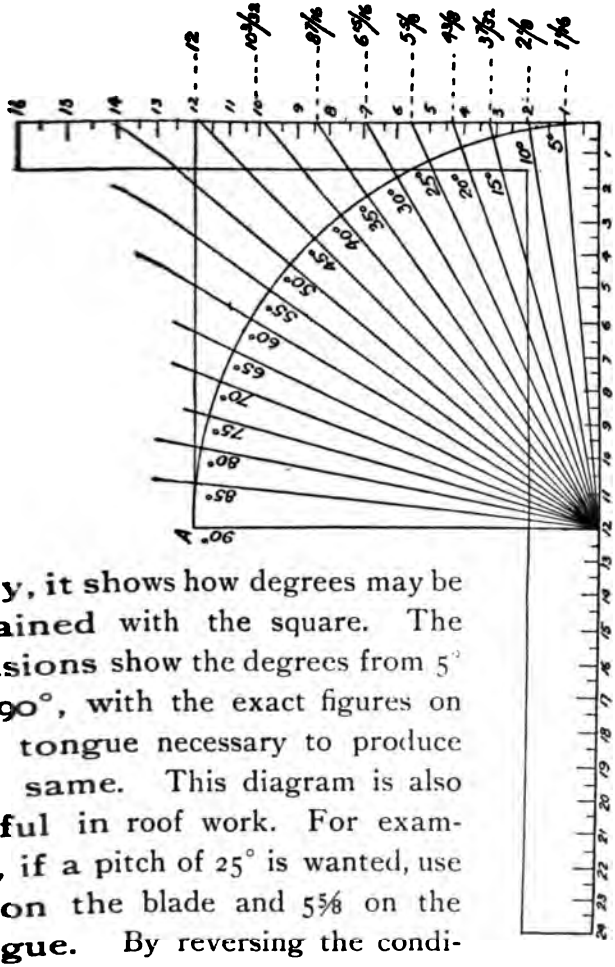


FIG. 83

ently, it shows how degrees may be obtained with the square. The divisions show the degrees from 5° to 90°, with the exact figures on the tongue necessary to produce the same. This diagram is also useful in roof work. For example, if a pitch of 25° is wanted, use 12 on the blade and 5⅝ on the tongue. By reversing the conditions 65 will be established.

In speaking of the square Mr. Stoddard says:

"The outside edge is divided into $\frac{1}{12}$ of an
the inside of the tongue divided into $\frac{1}{16}$, an
inside of blade $\frac{1}{32}$, while an inch on the f
the square in the corner is divided into $\frac{1}{144}$.
other side is divided into $\frac{1}{12}$ and $\frac{1}{8}$. The
mass of figures on the face of the blade
square is board measure. If you don't
stand it you should learn at once, as it i
simple. If you have a board 14 feet long
at 12 inches on the square. (That is whe
always look for length of board.) Fin
whatever the width of the board is move t
point. If it is 6 inches, the number of f
10 feet 6 inches. If a board is 10 feet lon
15 inches wide proceed the same as befor
you will find 12 feet 6 inches, and so on.
board is 16 feet, simply double the result
etc.

"The figures on the tongue are 'brace
ure.' You will
between the fi
of 2 and 3 i
$\frac{11}{12}$30. It mean
brace runs 18 i
and rises 24

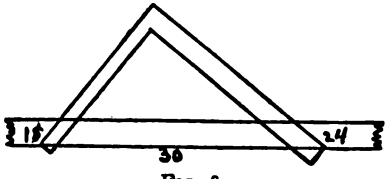


FIG. 84

feet) the length is 30 inches; or apply the s
as in Fig. 84 and you will have the length an

the brace runs 3 feet each way, or 36 inches,

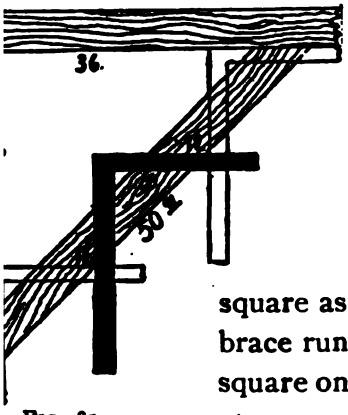


Fig. 85

you will find the length is 50.91 inches. But I don't use the brace measurements very much, as I prefer to apply square as in Fig. 85. If the brace runs 3 feet apply the square on 1 foot three times, etc.

he figures on the opposite side of square are
ying off an oc-
, and are used
s manner: Make
ter line in your
er, and from that

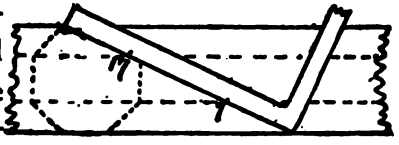


Fig. 86

neasure the distance on your square to the figure representing the width of your timber; that gives corner of octagon."

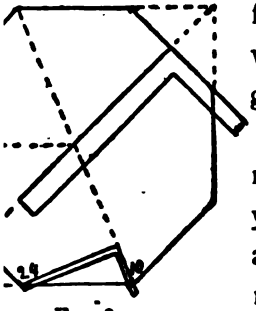


Fig. 87

Fig. 86 illustrates a much easier method. Lay your square diagonally across your timber and mark at 7 and 17, which

gives corner of octagon, 17 and 6¼ makes the correct line.

Fig. 87 shows how to lay off an octagon on the end of a timber. Lay the square on a line drawn from corner to corner, a distance equal to half the width of timber, square over, and you have one corner. Turn the square over and you have another, etc. The little square at bottom illustrates the octagon miter, which is 10 and 24; cut on 10. The octagon corner is a square miter. That is, if you cut timbers to lap at octagon corner they are cut on 12 and 12, or square miter.

If you should wish to miter a pentagon (5 sides) place the square on 9 and 12; cut on 9.

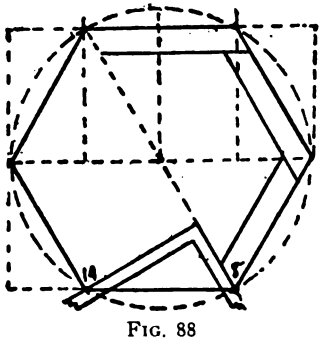


FIG. 88

Fig. 88 illustrates a hexagon. To lay off from a square timber divide two opposite sides into four equal parts, and the other two sides into two equal parts. A circle can be laid off into a hexagon the same way, as I think you can plainly understand from the illustration. The hexagon miter is 8 and 14, cut on 8. The corner is the same.

an accurate answer to problems that would otherwise take a long time, with many figures to figure out, and be liable to make mistakes besides.

Most of the foregoing examples are kindly furnished me by Mr. Stoddard, and while a number of them are similar to examples shown in previous pages, yet they offer to the reader different renderings of the same problems, and I have thought it proper to present them to the reader in the popular form given. Most workmen understand the plain language in which these examples and definitions are rendered, and it is the ardent desire of the writer and compiler of this work that its contents and diagrams be made as plain as pencil and the English language can make them, and to this end such material as that furnished by Messrs. Woods, Stoddard and others is gladly embodied in the book, as these gentlemen are past-masters in the art of handling the steel square.

The example shown at Fig. 90 for cutting in bridging is the invention of a president of a carpenter's union, and is employed by many workmen for marking off and cutting in bridging. It has many advantages over the old framer's method of striking two chalk lines across the edges of joists, and is more scientific.

ire across the square from 8 to 12, and it is iearly 14½, which is the length of rafter to one oot of run. Length and run, cut on length, ;ives the cut.

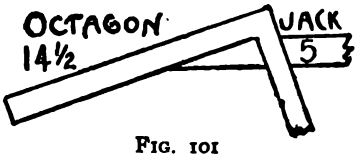


FIG. 101

Fig. 101, octagon ack. As the octagon niter on level surface s 5 and 12, it must aise same as common jack, and is, therefore, aised to length, or 14½, and 5 cut on length.

Fig. 102, hip rafter, s also length and run, cut on length.

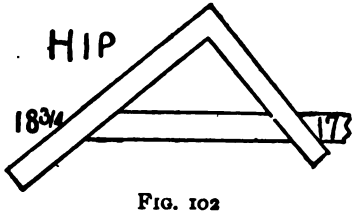


FIG. 102

Fig. 103. To bevel top of hip take length and rise and mark on rise.

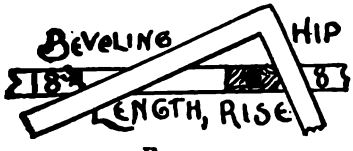


FIG. 103

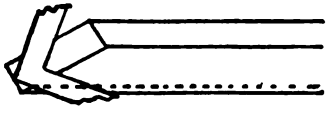


FIG. 104

Fig. 104 is another practical way, which is simply to lay the square on heel or hip. The illustration explains itself.

Perhaps the most practical way of all to frame a roof, the simplest to understand, easiest to

remember, and most rapid to apply is simply to always take the rise and run, measure across the square which gives length. Rise and run gives cuts, so you have it all.

Fig. 105 illustrates a roof 25 feet wide and a rise 10 feet 9 inches, run 12 feet 6 inches. Measuring across the square from 10¾ to 12½ gives 16½, or, 16 feet 6 inches is the length of rafter.

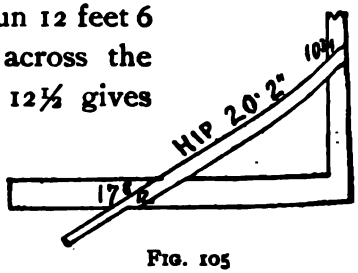


Fig. 105

Fig. 106. If the run of common rafter is 12½, the run of the hip will be diagonal of 12½, which is 17⅞, as is plainly illustrated.

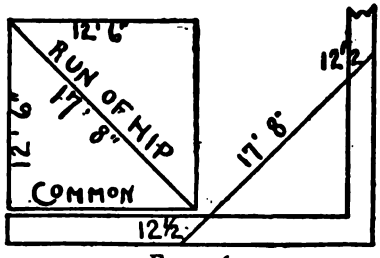


Fig. 106

Fig. 107. As the rise is 10¾ and run 17⅞, the length will be 20 feet 2 inches.

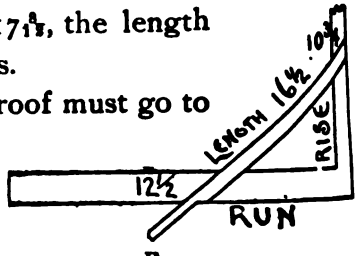


Fig. 107

Fig. 108. When a roof must go to a certain height to strike another building at a given point, as in additions, porches, etc., don't forget in getting the rise from

:o given point to allow the squaring up of as illustrated; and also remember to allow dge whenever one is used.

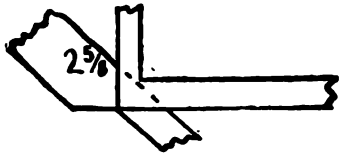


FIG. 108

Fig. 109 illustrates the cut of top of quarter-pitch rafter to lay on top of roof just mentioned. To apply the square first lay it on 12 and 6, which is quarter-pitch, and gives plumb-cut. From plumb-cut lay off pitch of main roof 10¾ and 12½, which gives cut.

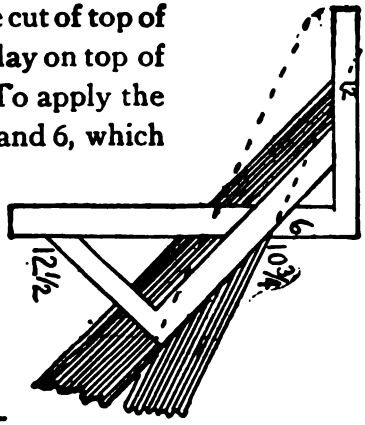


FIG. 109

Anyone that has studied this with a determination will have no trouble in framing any ordinary roof, as the general principles apply to all roofs, pitches, etc. So I will not take up any more space with roof framing at this time, but remember all sheathing, studding, cornice, etc., are made on the same cuts. In fact a hopper is also exactly on the same principle.

MISCELLANEOUS RULES

To make an ellipse for a three-foot opening, one foot high, drive a brad in a lath 1 foot from end, which gives height; another 18 inches from end, which gives one-half width; apply as illustrated in Fig. 110, reverse the square and it is completed.

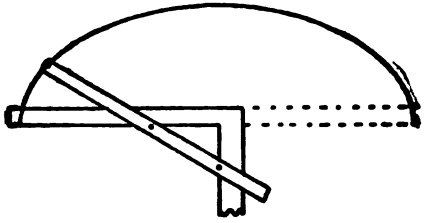


FIG. 110

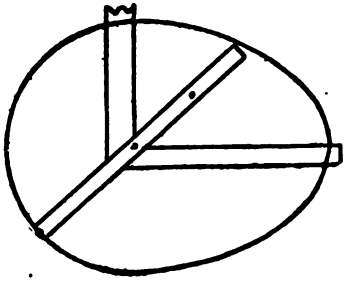


FIG. 111

Fig. 111. To make an oval, begin same as on ellipse, swing around on the one brad, which will make a circle at the large end, and it is formed as illustrated.

Fig. 112. To bend a board for a circle, if the given length is two feet, saw in and bend the board up until the joint is closed. If the saw is

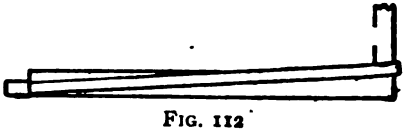


FIG. 112

very coarse it will raise at end about 2 inches. Therefore, saw in every 2 inches.

Fig. 113. To find the number of courses of shingles for a roof. If they were 4 inches to the weather it would be three to the foot, and very easy. Therefore, to get any number practically as easy, is the point. If

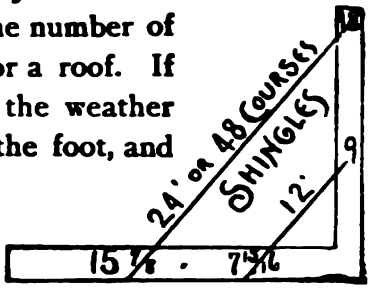


FIG. 113

4½ inches, two courses would be 9 inches. To get one foot length and only 9 inches actual measurement place one end of a foot at 9, swing around until the other end of the foot strikes the square, which is at 7¹⁵⁄₁₆. If the roof is 18 feet, measure from 18 parallel with the line just made, and it strikes the square at 15⅞, and the line from 18 to 15⅞ is 24; two courses to every foot diagonal measurement gives 48 courses. This may seem a little complicated at first, but when it is fully understood it can be applied instantly. Any numbers can be applied the same way.

Indeed it is impossible to say what cannot be done with the square, as I will show in Volume II how it may be employed as a calculating machine of considerable power.

In order that the reader may better under-

stand the handling of the square for laying out braces and simple roofs, I submit the following, which is somewhat different in application than some of the foregoing rules, though on the same principle. For example, if you wish to frame a brace for 4-foot run you lay the stick, or piece of timber, with straightest edge toward you. Taking the square at 12 inches on blade and 12 inches on the tongue, lay it on the stick, making a mark along the edge at the 12-inch mark on the square. Lay it on along the stick four times, which will give you the exact length between shoulders. The tenons must be added. Perhaps I can make it more satisfactory by giving a rough diagram. Let AB, in Fig. 114, represent timber for the brace. Lay the square on four times, as indicated, which will give you the exact length of

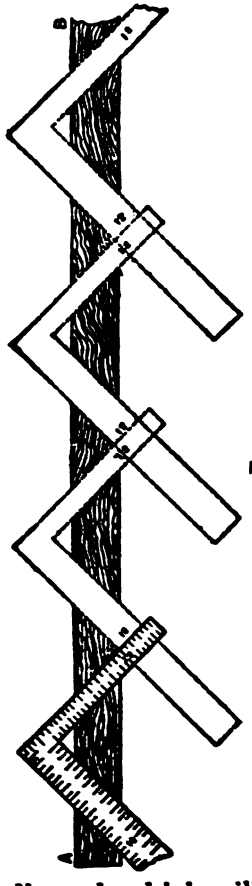


FIG. 114

a square of 4-foot rise and run. All square run braces may be made in same manner. For 3-foot run lay on three times, 5-foot run five times, 6-foot run six times, and so on.

In Fig. 115 the method of finding length of brace with 4-foot run and 6-foot rise is illustrated. You will notice the square is laid on at 12 and 8. It is to be repeated six times, as I have explained in connection with the other figure. The blade will give the bevel for one end, the tongue for the other. In all square runs the bevel is the same at both ends. By same method, also, you can find the length of all kinds of rafters.

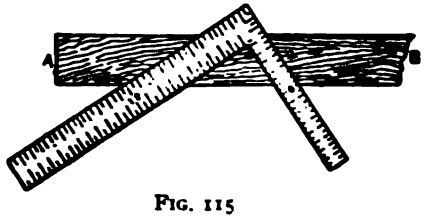


FIG. 115

In making a "draft," or drawing, for finding bevels and angles for braces or odd-shaped roofs, where angles are intended to be laid out with the square, it is best to make a scale of one-twelfth full size, which is most convenient in the use of the square for any purpose. By this scale each inch of the square represents a foot full size, and each twelfth of an inch of the square an inch full size. By using the square then as a scale, and reading measurements

made upon it as feet and inches, instead of inches and twelfths of inches, lengths of braces, etc., are very readily ascertained.

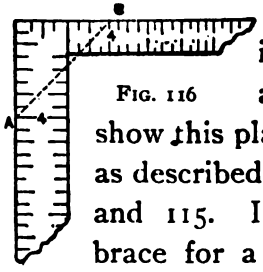


FIG. 116

This is practically illustrated in Figs. 116 and 117 of the accompanying sketches, which show this plan applied to the same braces as described and illustrated in Figs. 114 and 115. In Fig. 116, for obtaining a brace for a 4-foot run and a 4-foot rise set off 4 inches from the heel of the square along each arm, as shown by the points A and B. Then with another square or the pocket-rule measure between the points across the angle of the square, as shown by the dotted line. Note the distance from A to B in inches and twelfths of an inch, and read it feet and inches, which will be the length of the brace between shoulders. The tenons must be added

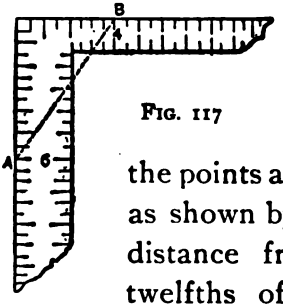


FIG. 117

The operation for a 6-foot rise and 4-foot run is illustrated in Fig. 117. Set off 6 inches for the rise, as shown by A, and 4 inches for the run, as shown by B. Take the distance from A to B which read in feet and inches as before explained.

bevels for the ends of the brace are to be
ed in the same general manner as
ɔed, by applying the square direct to the
. In the last example it will be noticed
ıe proportion of 6 to 4 and 12 to 8 is the
so that so far as concerns the bevel it is
erial which figures are used in placing the
. 18 and 12 and 24 and 16 will also give
me bevel.

is desired to cut a miter box by aid of the
for raking mouldings, it can be done as
s: Draw the
, ABDC, Fig.
ıd lay off CF
same pitch as
of. From C
ter, with CF
ius, describe
c FE. Con-
and E. Then

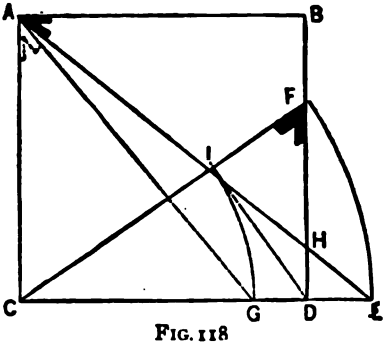


FIG. 118

e bevel at A be the cut across the top of
nd the bevel at F for side of box. The
lines of this figure represent the box or
s may be. It will readily be seen that the
are correct, as GD is equal to DH, and
ows the gain of the rafter.

y carpenters cannot understand why it is

that if 12 and 12 on the square, when
on a line, make an angle of 45° on th
either blade or tongue,
12, when laid down on
line, do not make a mi
octagon. The reason
and 6 will not give th
an octagon (20° 30'),
and 12 give a cut for n
is because the tangent
the radius being
4.97052,
the tang
equals 1
give the
rule for
ing the c

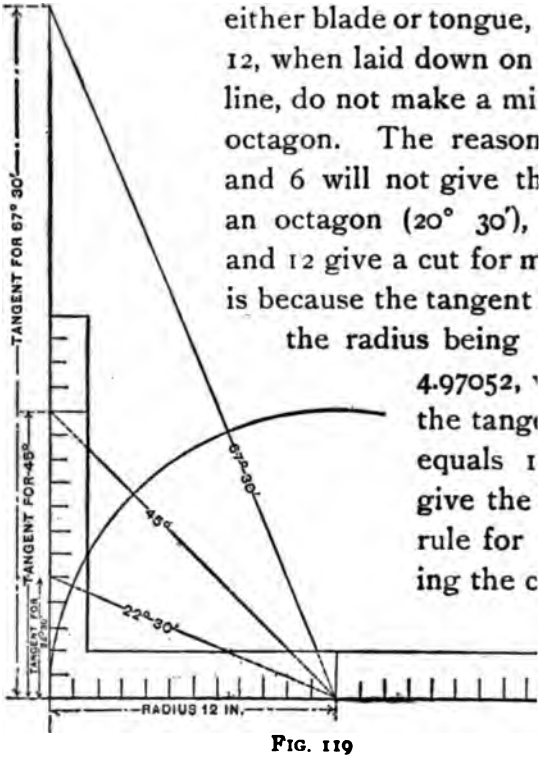


FIG. 119

steel square for any acute angle:
length on the blade as radius, then
on the tongue will equal the tangent
quired angle. The accompanying dia
119, illustrates the principle.

A few examples furnished me by

Woods, and which are out of the general line, are presented at this point to illustrate some of the possibilities of the steel square. An opening for a round pipe in a pitched roof or partition at any angle may be found as shown in Fig. 120. Here we have a 6-inch pipe intersecting a two-thirds pitch. A line from 12 to 16 on the square represents the pitch. Now with 12 as center and with radius equal to one-half of the diameter of the pipe draw a circle and square up from the tongue to the pitch, as shown at BC. Then AB represents one-half of the short diameter, and AC one-half of the long diameter. Now to make our illustration more clear we will transfer these lengths to a line at right angles with the tongue, crossing at 12.

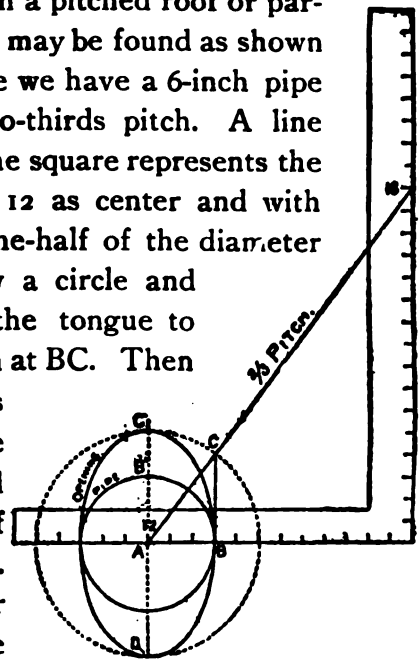


FIG. 120

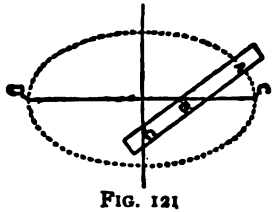


FIG. 121

There are several ways of finding the corresponding opening. Probably as good a method as any is that

shown in Fig. 121, which is as follows: Take a straight-edge, and on it space off A, B', C', as shown in Fig. 120.

Now draw a line equal to the long diameter, CD, and bisect it at right angles, and to these lines apply the straight-edge, as shown in Fig. 121. Always keeping BC on the lines and marking at A will describe the required opening.

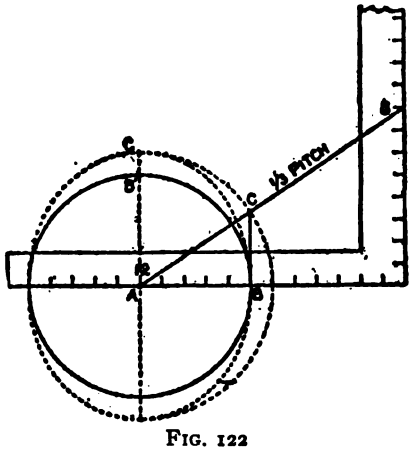


FIG. 122

The steeper the pitch the longer will be the required opening. In Fig. 122 is shown the same formula, but with the one-third pitch and a 10-inch pipe. Fig. 123 shows another method of obtaining the opening, and is as follows: Lay off the run,

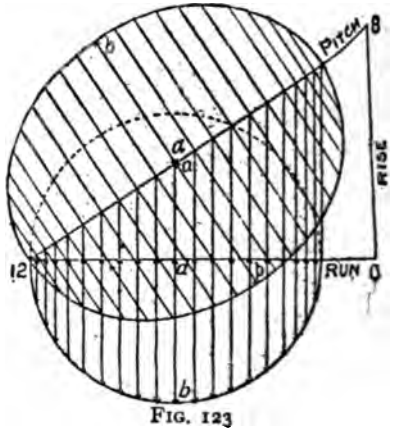


FIG. 123

: and pitch, and with one-half the diameter the pipe as radius, with the pencil point rest- g at 12, and center on the run, draw a semi- rcle. Divide the diameter into any number spaces and through these, run lines at right ıgles with the run from the circle to the tch. At point of intersection on the pitch raw lines on either side at right angles and on ıis measure equal the length of the correspond- g lines of the semi-circle, as at AB. Run an f-hand curve, touching these points, will give e required opening.

Suppose we wish to cut in two cross braces in timber construction, such as a barn, or a idge, or similar work as shown in the sketch g. 124, we will make the dotted line F repre- nt the distance apart on centers of the tops or et of the braces, and B the perpendicular run. t *t* and *b* be taken on the tongue and blade of square respectively according to scale. ke the cut of *t* for the top or the foot of the ıces. The diagonal distance from *t* to *b* is the gth according to scale. For the cross cuts rk along *b* and extend the line thus made. ain, apply *t* and *b* to this line, and mark along hich will be the cut required, as shown at C. may say that the reference letters are

intended to represent actual and proportionate measurements; actual when applied to runs and

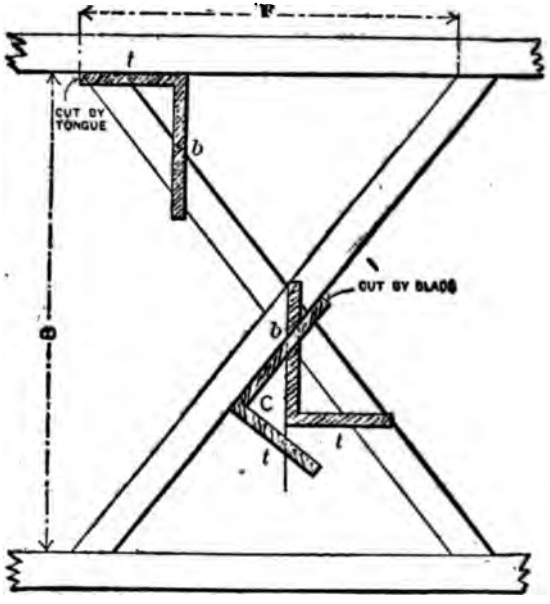


FIG. 124

other measurements of braces, and proportionate when applied to optional scale measurements by the steel square. The letters *t* and *b* are used because they are the initials of tongue and blade, and consequently suggestive. The principle is general, and applies to all similar cross braces of rectangular frames.

Another method for a single post is shown at Fig. 125, where the brace or leaning post is

ed into sill and girt. First lay out the tenon, then sure along that point 12 to the shoul- of the next ng, laying out int e r vening ctions and ing across al- from the out- ner or angle s a "sawed," m the "line" a "hewn" tim- Now, a lean- brace of the in point is ng more than

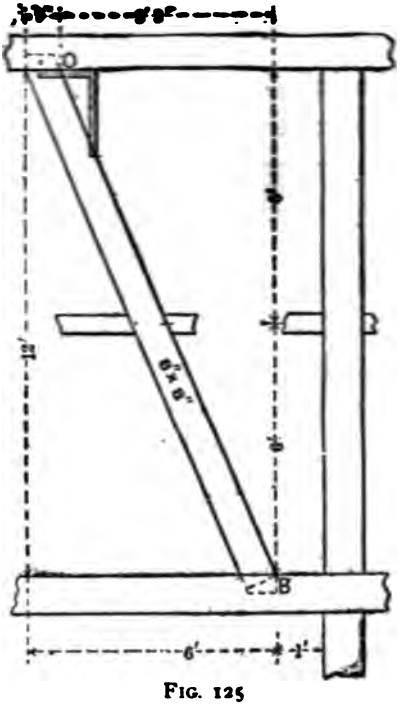


FIG. 125

ning post, and in this case the post leans 5 inches from the perpendicular. So in the way lay out, not from "toe to toe," but "toe to heel," or on the line BO. In prac- is always best to lay out the mortises for eaning braces in the parallel timbers with un from "center to center," which is the as from "toe to heel."

According to the foregoing argument, then, the run is not 6 feet, but 5 feet 3 inches. And we proceed to lay off the brace, using 24 inches on the long and 10½ inches on the short blade of the square, and applying to the corner of the timber, or to the "line" parallel with it as the case may be. Either B or O may be used as a starting point, the result will be the same.

This example is, of course, for one particular case, but it will give the reader a suggestion of how he may deal with all cases when there are leaning posts or braces of irregular runs and rise. I will deal with this subject at some length in the succeeding volume.

Carpenters, as a rule, do not thoroughly understand how to miter fascia and crown mouldings in cornicing hip and valley roofs. I will now present a problem in mitering, which is frequently met with in the usual practice of building. Fig. 126 represents the plan of a hip and valley roof, the main part being a plain gable roof, and the wing part is hipped, forming two hips and two valleys, as shown in the sketch. We will suppose that the ends of the rafters are to be cut square with the roof, which is one of the most common methods of putting up cornice.

There is nothing bothersome about the joints except in the valleys and on the hip corners.

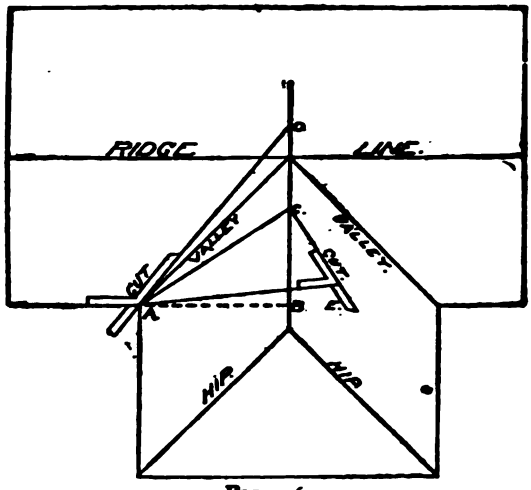


FIG. 126

With these joints there is a double bevel to the miter, which seems to lead a good many mechanics to resort to the old cut and try rule. The proper bevel to cut may be readily found from the diagram, Fig. 126. After drawing the hip and valley lines and ridge lines, showing the plan of roof, set off the run of common rafter, as shown by dotted line, AB. Square up the rise of common rafter, as BC, and connect A and C for length of common rafter. Take the length of common rafter just found and set it off from B to D, connect A and D. For length and position

of valley rafter for finding the bevel across the edge of fascia, set the bevel with the stock on the plate line and the blade on the line AD. The blade gives the cut as shown in sketch. Next square down from C the rise of common rafter, as CE, and connect A, E, which completes the lines for finding the bevel across the face of fascia board. Set the bevel with stock on line AE and blade on CE; blade gives the cut. The diagram shows the bevels for cutting the fascia and mouldings. Do not confound them with the bevels for cutting the rafters, for they are entirely different, and it would be an exceptional case if they were ever found to be the same.

I will now show, by means of the steel square, how to determine the proper figures to use for making the cuts. We will take a third-pitch roof for example. As a third-pitch roof is indicated by 12 inches run and 8 inches rise, we will take 12 inches on the blade of the square and 8 inches on the tongue, as shown in Fig. 127. Draw the diagonal, which will represent the length

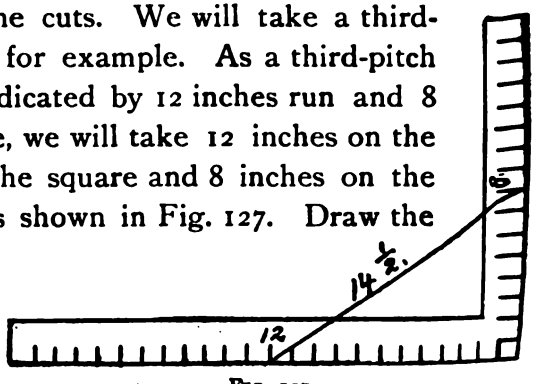


FIG. 127

of common rafter to the foot run of the given pitch, and which is very nearly 14½ inches. This is near enough for all practical purposes. We now have all the figures, which, if properly applied on the blade and tongue of a square, will give all the cuts. Take 12 on the blade and 14½ on the tongue, and the blade gives cut for edge of fascia. Take 14½ on blade and 8 on the tongue, and tongue gives cut for side or face of fascia.

Mouldings cannot very well be cut without a

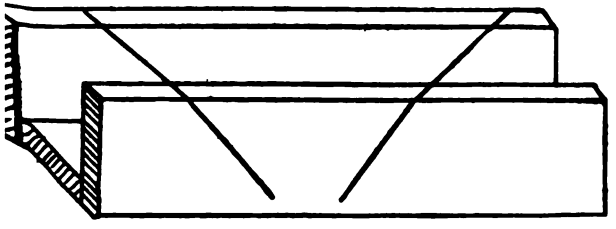


FIG. 128

ter box. Fig. 128 represents the manner of making the box with the cuts as described, by the square. Lay the square on top of box corresponding to the figures 12 and 14½ and scribe the 12-inch side for the cut across the top of box. Reverse the square and scribe on the 12-inch side as before. This is necessary in order to obtain a right and left cut in the box. For the cut down the sides of the box lay the

square on corresponding to the figures 14½ and 8. Scribe and cut on the 8-inch side. Reverse the square as before, so as to complete both the right and left-hand cuts across the top of box and down the sides.

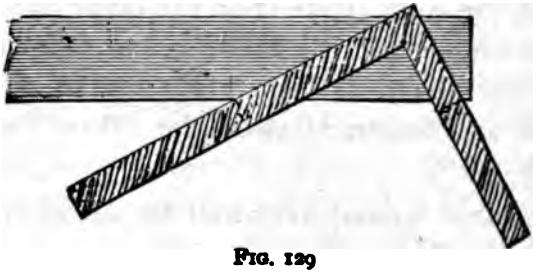


FIG. 129

The foregoing is largely taken from a paper published in "The National Builder," by J. P. Hicks, of Omaha, and while not altogether new

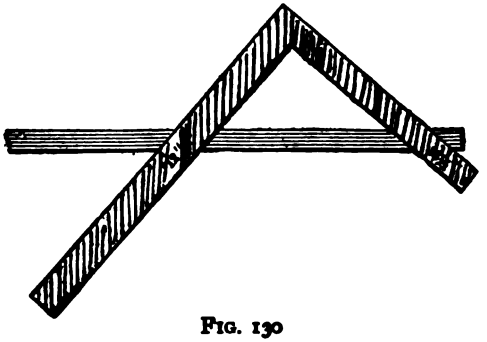


FIG. 130

is very ingeniously presented. Following somewhat on the same lines the illustrations shown at Figs. 129, 130 and 131 give another method of

utting the members of a raking cornice where he angle is 45°. Suppose, or example, the roof is quarter-pitch, it is necessary first to cut the level freize as if it were going square across the end of the building; then take the raking frieze and lay the square on

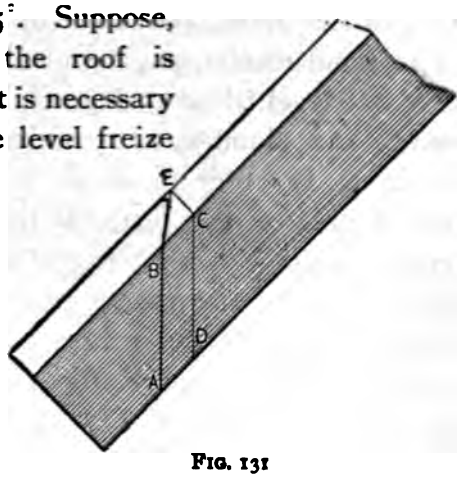


FIG. 131

the face of the board with the 6-inch mark on the tongue and the 12-inch mark on the blade, as shown in Fig. 129. Mark along the tongue to obtain the plumb-cut. In order to obtain the miter, measure across the square from the 6-inch mark to the 12-inch mark, which gives us very nearly 13½ inches. Now lay the square across the edge of the board, as shown in Fig. 131, with the 13½-inch mark on the tongue and the 12-inch mark on the blade; the tongue will then be level.

The rule is to take the rise per foot of the tongue of the square, and 12 inches on the blade, and measure across these two marks with

the distance may be, using it with 12 inches to obtain the miter, and mark by the long bevel. The same results may be obtained as follows: Cut one level frieze 45 degrees, or square miter; mark the plumb-cut on raking frieze where desired. In order to obtain the miter cut use the figures on the blade of the square, which corresponds with the length of the common rafter, and on the tongue those which represent the run of the rafter; cut by the blade. Some carpenters mark the plumb-cut AB, as shown in the sketch, Fig. 131, which I show, then draw the line CD parallel. The distance between the lines is equal to the thickness of the frieze. Square across the edge, CE, and draw the line from the first plumb-line to the square line on the other edge, as BE, which gives the cut as shown.

To find a line forming equal angles with two converging lines, AB and CD, Fig. 132, draw ED and BF parallel, and equally distant from AB and CD, intersecting each other at the point S; from the point S as center describe an arc, cutting the converging lines at the points P and R, which joined, give the line required.

The same can be found by the use of the square. Place, as shown, the square on the lines

AB and CD; mark from the point of intersection S, cutting the lines AB and CD at the

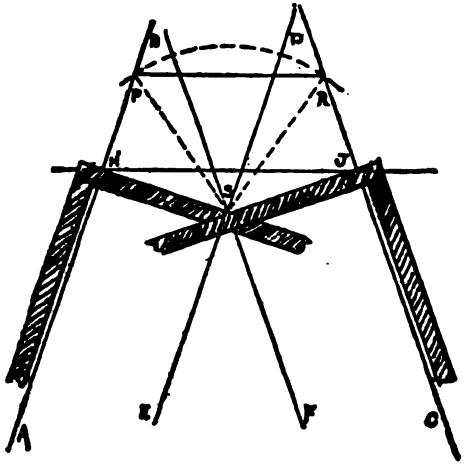


FIG. 132

points H and J, which joined give the line required.

The following very useful solutions were furnished me by Mr. A. W. Woods, architect, along with a number of others, which will be published in Volume II.

In some sections of the country with many framers, the rise is reckoned by the degree instead of a rise in proportion to the span. The rules in the application of the square for the cuts and bevels remaining the same, but in degree framing it requires a trigonometric

formula, or a protractor, to determine the r
In the absence of the protractor one may

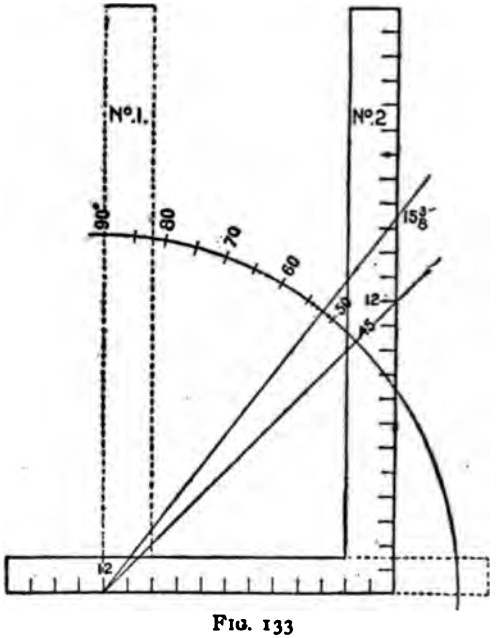


FIG. 133

temporarily devised as shown in Fig. 133, follows:

Lay off an angle of 90 degrees, which may done by marking from the heel of the squ along both the blade and tongue The squ we will say, being in the position of No. 1, with the angle as center lay off a quarter ci the radius of which may be any size desired larger the more accurate will be the result.

Now reverse the square, as shown by square
). 2, and with the 12-inch mark on the tongue
sting at the heel or angle of square No. 1. A
ıe from 12 to 12 will bisect the quarter-circle
an angle of 45 degrees. Now with a pair of
acers divide the arcs thus formed into nine
aces, which will make the divisions five
grees apart, and by dividing these spaces into
e equal parts will give the division of the
grees. However, it is only necessary to
vide that section containing the desired
gree. If it be 52 degrees then we divide the
ace about 50 degrees, as shown, and a line
)m 12 on the tongue and passing at 52 degrees
ll intersect the blade at 15⅜ inches and repre-
ıt the rise per foot in the run.

In Fig. 134 is shown a diagram of how to find
: lengths of the rafters to a given scale, also
: bevels that give the cuts. The square may
applied to the angles instead of the bevels, if
sired.

Without going further into the details of the
ıstruction of this diagram we will give the
ferent parts as follows:

Let AB represent the run or seat of the
nmon rafter, and with A as center lay off the
and proceed as in Fig. 133 for the pitch.

BC will represent the rise, AC the length of the common rafter, BF the seat or run of the

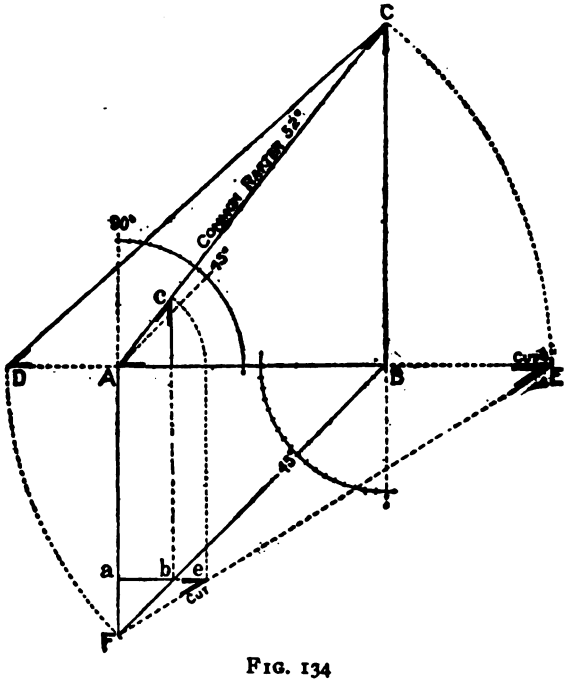


FIG. 134

hip (this line always rests at an angle of 45 degrees with AB, unless the adjoining sides of the roof are of a different pitch), and equals DB. DC represents the length of the hip and equals FE, the latter being drawn to obtain the bevels for the cuts. AE is obtained by dropping AC on a line with AB.

a, b represents the run of the first jack from

rner, and by squaring up to AC, as its length will be Ac, and represents the a difference in the lengths of the jacks. it and down bevels remain the same as common rafter, but require an additional cross the back to obtain the cut at the hip. This is found by extending rsecting FE, as shown at e. ll be seen that ae equals AC and may, re, be taken for the length of the jack. he backing of the hip lay off one-half of hip's thickness from C on line C'' and l give the gauge line of the cut at e to a center line at top of the rib.

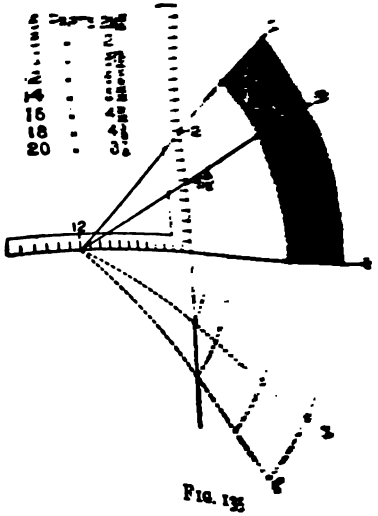


FIG. 135

The sectional part of a circular frame or wheel can easily be found by the aid of the square as follows: Draw line A, Fig. 135, and on it place the tongue of the square as shown, letting the 12-inch mark be the starting point.

Now suppose we wish to make a frame with eight equal parts. Draw a line from 12 on tongue passing at 12 on the blade, and on this lay off the desired radius, and swing down to A. The space from A to C will be the desired part. If twelve parts are wanted then draw the line passing at 6⅛ on the blade. The part from A to B being that proportion.

If one-half the parts mentioned above are wanted then these parts may be doubled, or found as shown by the dotted lines below A. Great care must be exercised in laying out the diagram, the last variation of which will be multiplied by the number of parts used.

When making frames of very large diameters, it is better to increase the scale by raising the figures given by doubling, trebling, etc.

SOME POINTERS ON ROOF FRAMING

No matter what people may say to the contrary, there is no method or methods that has ever been devised that is so effective in roof framing, or results so rapidly achieved, as those which are obtained by the use of the steel square. I have shown in some of the earlier pages of this work how readily the length, and bevels of any common rafter may be obtained by the simple application of the square, any determined number of times. Thus for a building of, say, 30 ft. in width, which is to have a roof of any given pitch, we arrange the pitch as I have shown, with so many inches on the blade for the run, and so many on the tongue for the rise This settled, we apply the square fifteen times to the rafter. 15 being half of the width of the building. This then gives the length of the rafter, and a line drawn along the edge of the tongue of the square will give the proper bevel for the top or plumb cut. If there is to be a ridge board on the roof, then half the thickness of such board must be measured back on the line drawn, and the rafter must be cut at that

point, this provides for the ridge board being nailed on the face of the cut without in the least changing the pitch.

A line along the edge of the blade, gives the proper bevel for the level or horizontal cut. If the bottom end of the rafter is to have a crow-foot cut on it to fit the plate, the workman will have no difficulty whatever in cutting the foot of the rafter to suit, as all the lines will be at right angles to each other, and a section of the plate may be made on the line of the bevel and the "cuts" laid off to suit the conditions.

In reviewing an article of mine on this method of laying out a rafter, an English carpenter took exception to it on the grounds that it would take too much time to lay out the rafters for a whole building by this "tiresome process," as he called it. Now, the Englishman was right from his point of view, but no American workman would ever think of laying out the rafters for a whole building by the process. He would simply make one rafter as I have shown for a pattern, and use this pattern for laying out all the other rafters for that particular pitch and rise on the same roof. Most workmen, however, make a pattern from thin stuff of some sort, as it is lighter and easier handled. The reviewer sug-

gested as a better way "that the pitch be arranged on the iron square, then measure across the angle from the points of run and pitch, and multiply this measurement by half the width of the roof to be covered." Now, this is all right, but, as a matter of fact, entails more labor of a "tiresome sort" and would use much more time than the method I have taught now for nearly forty years. The American workman, however, does not even require a suggestion as to the quicker method. He will see and adopt it at once without argument.

The method the Englishman would adopt is shown at Fig. 136, where the points of pitch and run are shown at 12 and 8, which makes the diagonal line 14½ nches. To get the length of the rafter or our supposed uilding then, we nust multiply this 4½ inches fifteen imes, then we must use the square at the top nd bottom of the timber to obtain the necessary evels for the cutting lines.

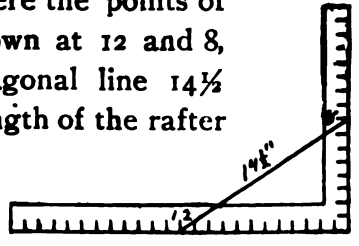


FIG. 136

Regarding this question of preparing rafters or a common roof, an "old hand" in the use of he steel square writes to me to say: "I do not

think that any simpler method can be given for finding the bevels at the heel and point of rafters than that which you have explained in your books, but, I do think that the following method for obtaining the lengths of rafters, is somewhat better than yours, particularly when employed for estimating purposes. The most common width of buildings in my locality is 24 ft., and with your permission I purpose to take that width for the practical test of my method. As you have given several ways by which the same result can be obtained, I will ask you to compare them with mine.

Finding the length of the hypothenuse by the old rule, we obtain for a one-quarter-inch pitch 13:4.99, or, as near as it can be used on the square 13 feet 5 inches.

Allowing one inch to the foot and trying your method we find, as the result, 13 inches and 7-16 scant, or 13 feet 5 inches. This is a very simple method, and when the rule is kept perfectly straight, the results are very satisfactory.

By my way I simply multiply the width of the building by the decimal .56, 24 × .56 = 13.44, or as near as can be worked by the square, 13 feet, 5 inches.

Let us try the same rule for a greater width—

say 60 feet. By finding the hypothenuse we find as near as can be used by the square, 33 feet, 6½ inches. By my method it would be 60 × .56, or 33.60, equal to 33 feet, 7 inches full. By this method the rafters in wide buildings are a little long. Thus, if the building is 52 feet wide, by the hypothenuse it would be 29 feet, 1 inch; my way it would be 29 feet 1½ inches. I consider this an advantage, as it leaves the point of the rafter very slightly open.

For a one-third I follow the same plan, only using the decimal .6 Unlike the decimal used for a quarter pitch the lengths are a very small fraction short; as, for instance, a rafter for a building 60 feet wide, by finding the hypothenuse, would be 36 feet, $\frac{1}{8}$ of an inch. By my way, 60 × .6 = 36 feet. A slight difference, truly. If building is 48 feet wide, then by the first method we find 28 feet, 10 inches full; by my way, 28 feet 9⅜ inches. A little practice will enable the mechanic to allow just enough to make up for the slight difference, so that when rafters are put together the fit will be perfect.

The one-half pitch can be found in the same manner by using the decimal .71. Taking the 4-foot building, length of rafters by the hypothenuse, we find 16 feet, 11⅓ inches; my way they

would be 17 feet full. Again, building 60 feet wide, rafters by the first method would be 42 feet, 6⅛ inches; by my way 60 × .71 = 42 feet, 6 inches. By using this decimal, the length is so near practically correct, that it may be used in all cases.

For a full pitch use the decimal 1.12, and as in the preceding mentioned pitch, and it will be found so near correct that it can be practically used in all cases.

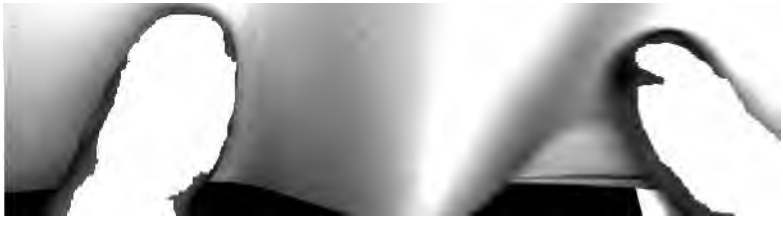
It will be noticed that I have not made any allowance for projection of rafters over the plate. In this case gauge from the crowning side of your rafter the thickness of your projection; allow enough for the latter, and find the lower bevel according to the way you described in your last; measure the length of your rafter from where this bevel crosses the gauge line.

A little practice will enable the mechanic to lay off a rafter in a very short time. I have used the above myself, and have no trouble whatever. While I have no fault to find in your methods as I know them to be correct, yet it is just as well that workmen should know other methods, as there are many occasions when the "only method" he possesses, cannot be applied. Hence I submit the foregoing, at your request

W. H."

All this is very true, and right as far as it goes ut it so happens that many workmen do not ave the necessary learning to work out these problems in roofing on the lines laid down by W. H., but, in order to meet conditions of this kind I have prepared a series of tables which I will insert in the next volume, giving the length of rafters for any building having a width of from five to sixty feet and a rise of roof of from one to eighteen feet to ridge. This will cover the whole ground, and form a ready table for the estimator to take his measurements from.

I may be pardoned for again showing the common and simplest method of laying out an ordinary rafter, for notwithstanding all I have said and described and explained on this subject there will always be some persons who will not be able to grasp the method, unless I put it to them in some other light. I am sure of this from the long experience I have had in answering of questions of this kind through columns of different building journals, no doubt owing to some constitutional peculiarities of both the person who asks the question and the person who attempts to answer it. This is one of the main reasons why I have admitted into this work various methods and



descriptions of others than myself, so that readers will have the same methods described and explained to them in several different ways by several writers

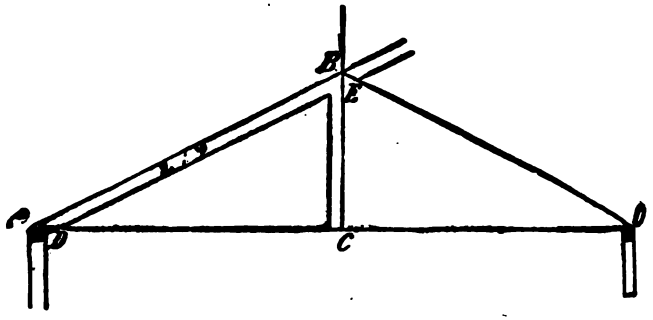


FIG. 137

Let us take the diagrams shown at Fig. 137, which shows a portion of a roof having a quarter pitch. CEB showing the height, and AB the length and inclination of rafter. D shows the foot of the rafter on the plate, cut "flat foot" and the line EC the plumb cut. This is quite plain. The building may be any width, let us say in this case, that it is 30 feet wide from A to O. That will make the distance from A to C 15 feet.

A method of obtaining the bevels for this rafter is given in Fig. 138 where the steel square is shown laid on the pattern with the points 16

inches on the blade and 8 inches on the tongue applied to the edge of the stuff. The line HO on the blade gives the bevel for the foot of the

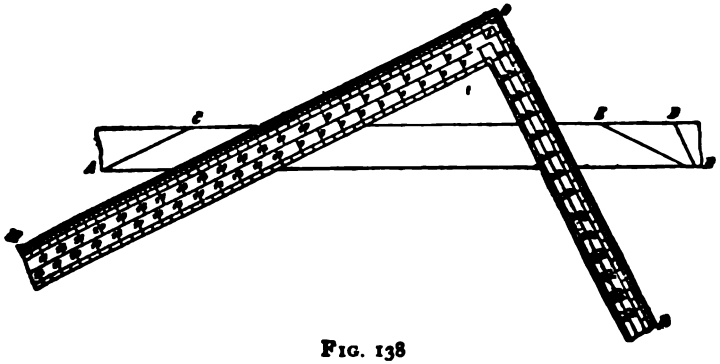


FIG. 138

rafter AC, as shown both in Figs. 137 and 138. The line OP, Fig. 138 gives the bevel for the top of the rafter or the plumb cut, as most workmen call it. Now, there is nothing in this diagram, which is from Bell's Carpentry, an excellent work,—from which the workman can get the length of his rafter, without complicating matters. Had the figures 12 inches and 6 inches on the square been employed instead of 16 and 8, then the distance across the diagonal from these two points would have equalled on the rafter, one foot on the base line, or seat of the rafter, so that 15 times that length would have been the total length of the rafter. Better still, however,

would have been the application of the square 15 times on the edge of the rafter pattern with the points 12 and 6 on gauge points, then both length and bevels would have been obtained at one operation.

The following, which has been kindly furnished me by A. W. Woods of Lincoln, Neb., will I am sure, help the student to an understanding of the subject of roof-framing generally. This relates more particularly to the framing of hip and valley roofs, a phase of the subject requiring study and attention of the learner.

Mr. Woods goes on to say: Much has been said and can be said on the subject, but it is my aim to say as little and and do as much as I can to make the subject clear. Every carpenter knows that the run and rise of the rafter taken on the square will give the seat and plumb cuts, but inasmuch as buildings are not all of the same width, it requires a different set of figures for each run, and as it requires an extra calculation to first find the run of the hip or valley, it is better to use the full scale for a one-foot run of the common rafter which answers for any run.

Referring to Fig. 139, we show a square bounded by A, B, C, D, the sides of which are 12 inches. E is at a point 5 inches from B, and

C 12 inches from B. B-A represents the run of the common rafter. E-A represents the run of

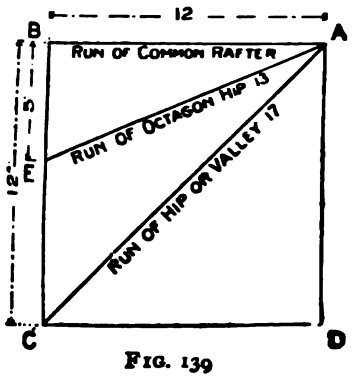


FIG. 139

the octagon hip or valley, and C-A the same for the common hip or valley,

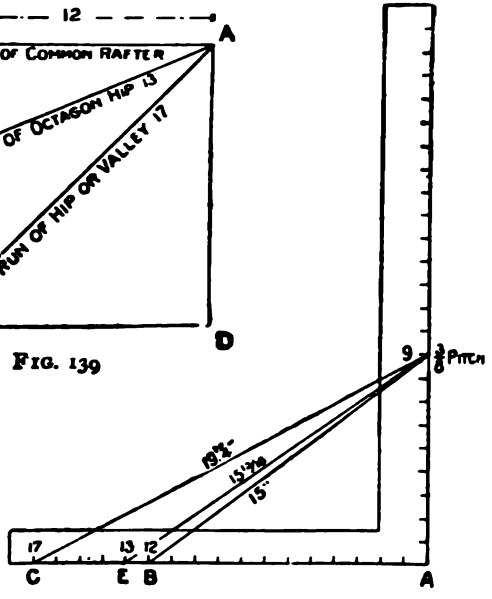


FIG. 140

their lengths, being 12, 13, and 17 respectively. Now since 12, 13, and 17 are fixed numbers, we take them on the tongu of the square, as shown in Fig. 140. Now suppose we want to find the lengths and cuts of the rafters for the 3/8 pitch. We take 9 on the blade. Why? Because the run being 12 inches, the span must be two times 12, which equals 24, and since the pitch is reckoned by the span, we find that 3/8 of 24 is 9, which rep-

resents the rise to the foot run. Then 12 and 9 give the seat and plumb cuts for the common rafter, 13 and 9 for the octagon hip or valley, and 17 and 9 gives the same for the common hip or valley. In Fig. 141 I show each separately.

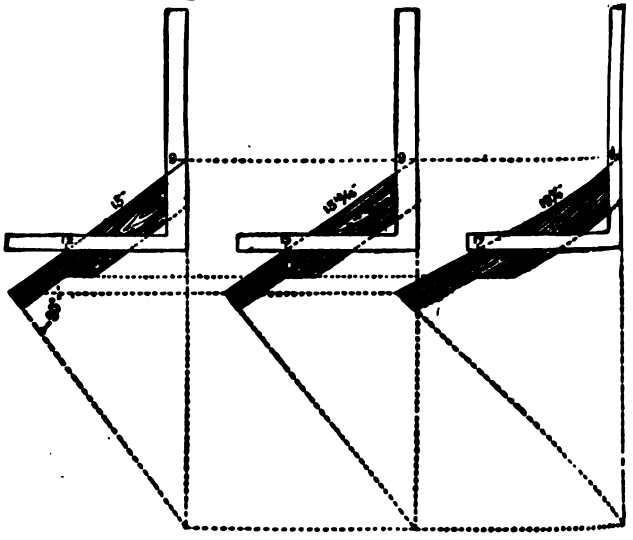


FIG. 141

The measurement line of hips and valleys is at a line along the center of its back, and just where to place the square on the side of the rafter so as to make the cuts and length come right at that point is a question that taxes the skill of most carpenters, especially so when the rafters are so backed. In Fig. 142, I have tried to make the above points clear.

irst, I show the plan of the rafter. The
ss lines on same represent an external corner

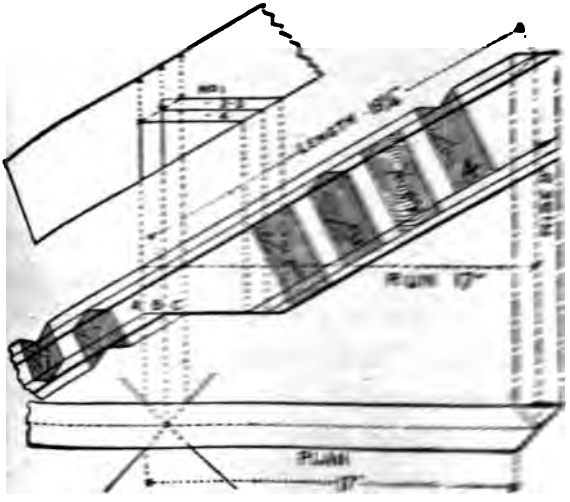


FIG.

for the hip and valley respectively
plan is shown the elevation
1-2-3-4 represent the position
under the following conditions
not backed, No. 2 hip when
when not backed, No. 4
No. 1 is outlined by heavy
than the others. By tracing
he sections down to the
o the second elevation will
he notching should be for

cuts into the right hand vertical line from the plan, which would make it stand at the right height above the plate, but in order to make the seat cut clear the corner of plate, it is necessary to cut into the center line above the plan. No. 2 cuts into the same points as No. 1, but owing to its being backed, the seat cut drops accordingly. No. 3 cuts into the center vertical line, and in order to clear the edges of the plate must cut out at the sides to the left vertical line. No. 4 cuts in the same as the latter, but as much lower than No. 3 is No. 2 is below No. 1.

The outer vertical lines from the plan represent the width of the rafter. Therefore if the rafter be two inches thick, would be one inch apart, and this amount set off along the seat line (or a line parallel with it) will give the gauge point on the side of the rafter. To make this clearer refer to Fig. 141; 17 and 9 gives the cuts. Now leaving the square rest as it is, measure back from 17 one-half the thickness of the rafter, and this will be the gauge line point from which to remove the wood back to the center line of hip, and the measurement from the edge of the rafter taken vertically down to the gauge point set off on the plumb cut regulates how far apart the parallel lines of the seat

cuts will be under the above conditions. This rule applies to any roof so long as the pitches are regular.

Proceed in like manner for the octagon hip, the variation, however, is practically one-half of the above results for the square cornered building

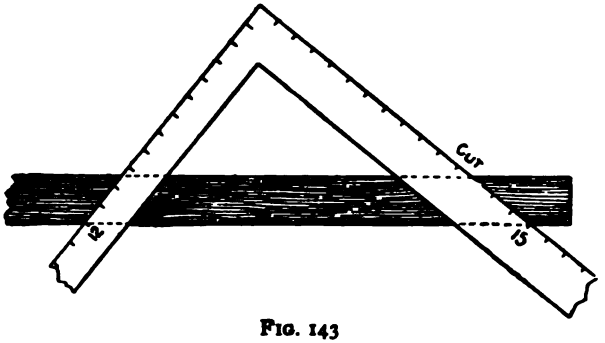


FIG. 143

Fig. 143 illustrates side cut of the jack, 12 on the tongue, and 15 (length of the common after) on the blade.

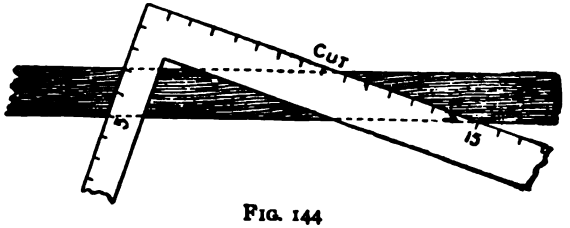


FIG. 144

Fig. 144 illustrates side cut of the octagon jack, 5 on the tongue and 15 on the blade.

Fig. 145 illustrates the side cut of the hip or valley, 17 on tongue, 19¼ (length of the hip) on the blade giving the cut in each case.

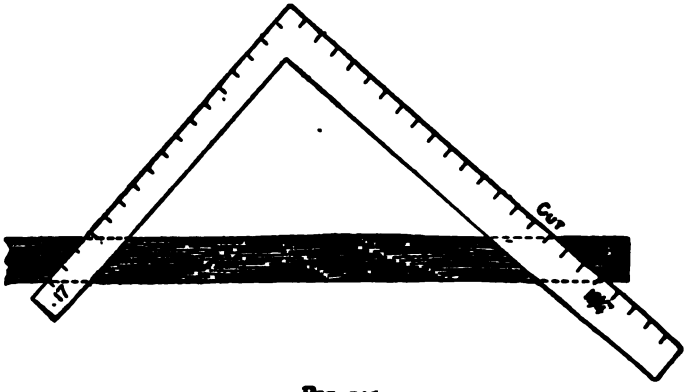


FIG. 145

The latter, however, is for the unbacked rafter. If it has been previously backed, then apply the square with the above figures on the lower edge at bottom of the plumb cut, or apply the square as for the jack, Fig. 144, to the backing line, which will give the same result as 17 and 19¼.

It is quite clear that when a workman cuts a common rafter he is also cutting a timber that would answer for a hip for a building of less span having the same rise, only taking some adjustment of the top bevel to fit gainst a ridge. This is quite plain, and if we refer to Fig. 146, we find that the common rafter for a 1-foot run

comes a hip for an 8½-inch run and that is p for a 1-foot run of the building becomes a ommon rafter for a 12-inch run. Therefore, ıe rule that applies to the common rafter also

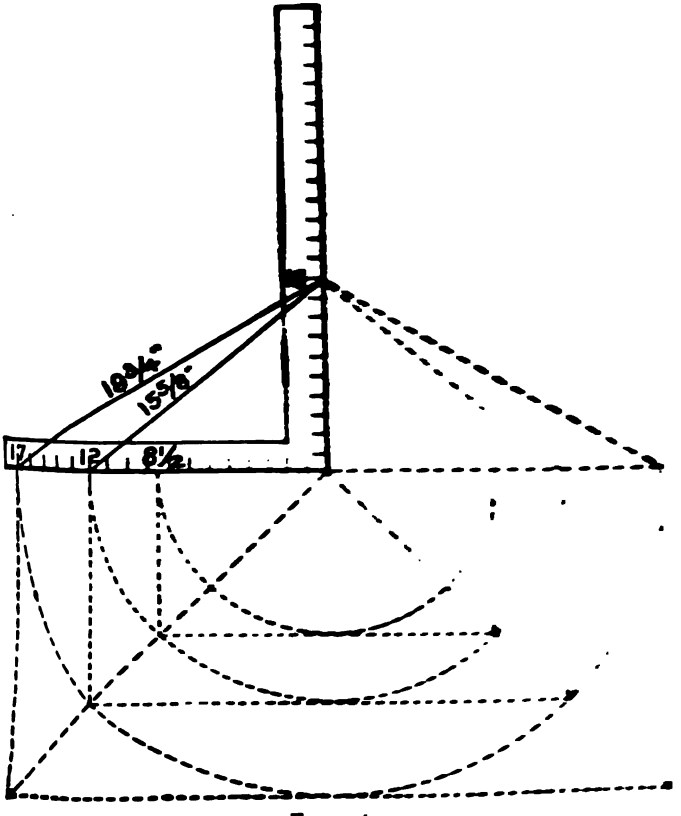


FIG. 14.

applies to the hip rafter, *i.e.*, the run and [illegible] taken on the square will give the seat and [illegible]

cuts. The run and length of the rafter taken on the square will give the side cuts, or taking the scale for a 1-foot run, Fig. 146, it is 12 on the tongue and the rise on the blade for the common rafter, and 17 on the tongue and rise on the blade for the hip. The tongue giving the seat cut and the blade the plumb cut. For the side cuts we take 12 on the tongue and 15⅝ inches on the blade, and the blade will give the side cut of the jack. Take 17 on the tongue and the length of the hip, 19¾ inches, on the blade and the blade will give the side cut of the hip. It would also be the side cut of the corresponding jack if it be a common rafter. Seventeen is used for a foot run of the hip rafter because the diagonal of a 12-inch square is practically 17 inches.

If we were to use 12 on the tongue for a foot run of the hip the rise to the foot would necessarily be less than 10 inches. In Fig. 147 I show what the difference is in rise to the foot.

From 12 to 12 is the length of the run of the hip, and this, taken on a continued line of the run of the common rafter, and an equal rise of the common rafter, set off as at A, and a line from this to 12 on the tongue passes at 7⅞ inches on the blade, because the common rafter having

f 10 inches to one foot, for one inch it have ⅛ of an inch, while the hip would ve ⅛ of an inch to h and for 12 inches it e 12 times ⅛ equals ½ inches. Therefore res given in the sec- istration would give ne cuts as those in it, but as the latter tates a calculation nds in fractions—

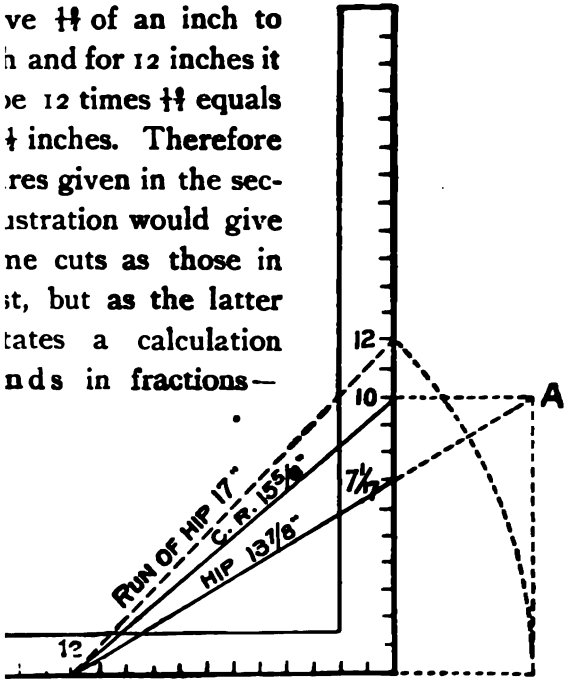


FIG. 147

is not given on the square—and for that 17 is generally used for a foot run for s and valleys.

AN UNEQUAL PITCH

ie matter of roofing over unequal pitches here is no ridge and when all hips meet.

the building being longer than it is wide, the backing of hips and their lengths and bevels would be a very easy matter if a drawing of the whole thing was made, but, to obtain these by the use of the square alone, is somewhat more difficult. Let us assume the building to be 18 feet wide and 28 feet long, and having a rise of

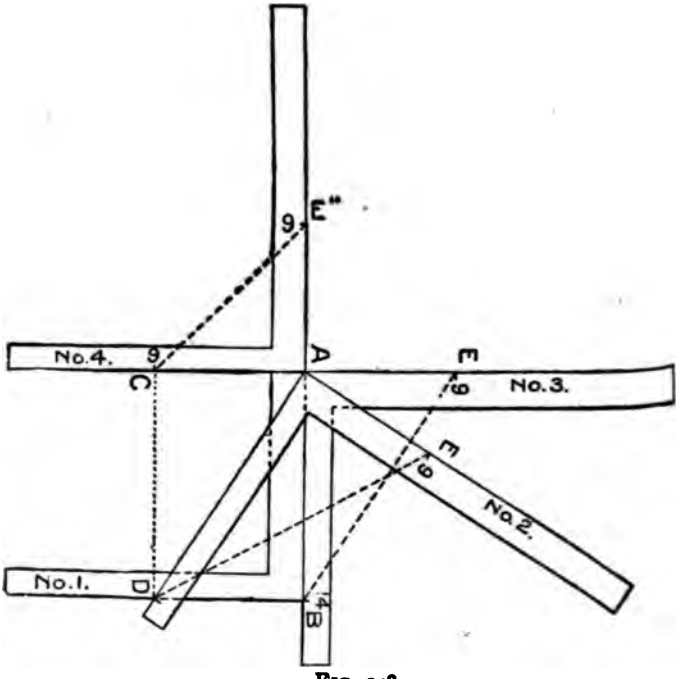


FIG. 148

9 feet, then, by referring to Fig. 148, we show to one inch scale the length, run, rise, seat, and

plumb cuts for the hip and common rafters as follows: The run of the long way of the building is 14, and 9 for the narrow way, which we take on the blade and tongue respectively, as shown on square No. 1, and to this apply square No. 2, as shown. AD equals the run of the hip. AE equals the rise and ED equals the length of the hip. The reader will notice that the letters A, B, C, D form a parallelogram, with side and ends equal to the runs of the common rafters. Therefore, by taking the runs on the tongue, as shown by the squares Nos. 3 and 4, will give their lengths, seat and plumb cuts.

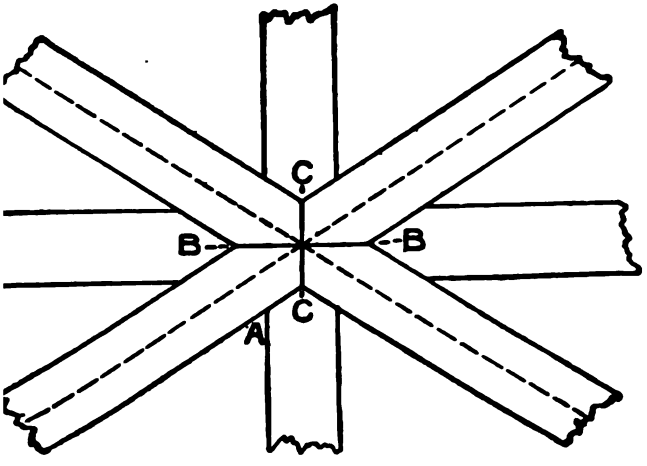


FIG. 149

Fig. 149 is shown the intersection of the

rafters at the peak and as the lengths of all rafters are scaled to run to a common center it is necessary that the common rafters must cut back so as to fit in the angle formed by the hips. The proper deduction for this is shown in Fig. 150 by placing two squares on the back of the rafter, with the heel or corner of the squares resting on the center line. The distance from the corner of the square to B measured square back (at right angles) from the plumb bevel, as shown in Fig. 148, will locate the point of the long common rafter at B in Fig. 149. Proceed in like manner for the short common rafter, taking the distance from the corner to C, and for the side cuts, take 14 on the tongue and the length of the short common rafter CE on the blade—the blade will give the cut at AC in Fig. 149. The reader will observe that this angle is the same at that for the side cut of the jack. Proceed in like manner for the long common rafter side, using 9 on the tongue and BE on the blade. These same figures will give the side cuts of the hip, provided hip has been previously backed. Taking the last for example the reader will observe that 9 on the tongue and BE on the blade the square would lay on the plane of the backing and the blade giving the cut along

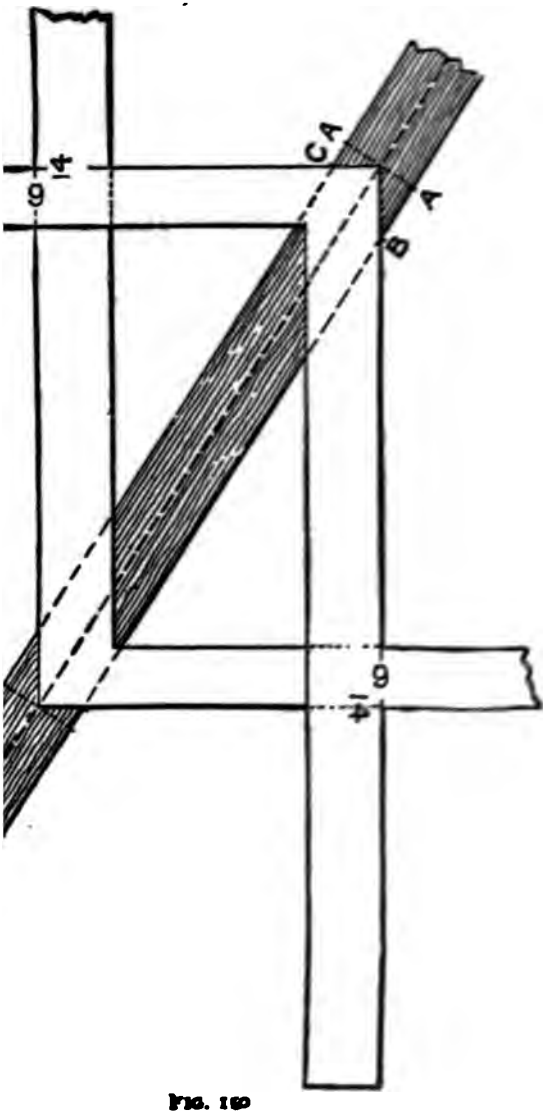


FIG. 150

the line BB in Fig. 149, or these cuts may be found by measuring square back from a plumb bevel at points A and A, Fig. 150, the distance AC and AB, which will give the proper plumb cut at the sides and intersecting the line AA at the center. These same distances, AC and AB, but transferred to opposite sides, set off on the seat cut or a line parallel with it, will give the gauge points on the side of the hip for the backing.

The lengths of the jacks may be found by dividing the length of the common rafter by the number of the spacings for the jacks; the quotient will be the common difference.

METHODS OF LAYING OUT A COMMON RAFTER

In several instances in this work I have endeavored to convey to the reader an idea of what is meant by the word *pitch* when referring to roof work. In many cases which I have met the phrase does not seem to be properly understood. Perhaps the following sketch, Fig. 151, and the description may aid somewhat in simplifying the matter. Let us suppose we wish to raise a roof and make it exactly a third-pitch; draw AB and AC at right angles as shown in Fig. 151. Describe an arc, as shown, from A as

Divide the arc in three equal parts as
ed by E and E'. Draw EA. Then by

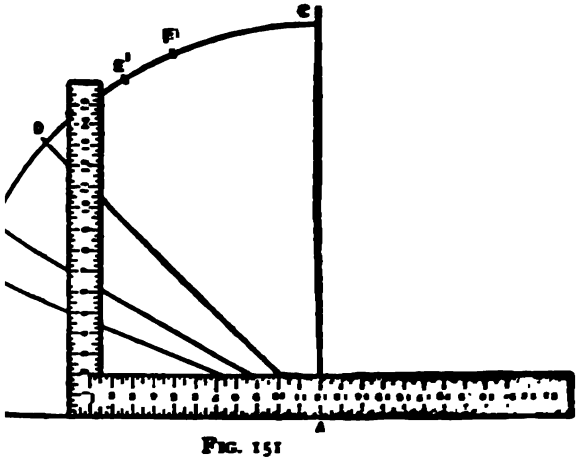


FIG. 151

; the square as shown, we find that third-
or a hexagon mitre, is 7 inches to the foot.
l of 8 inches, as some suppose. Divide
: in four equal parts, as shown by FDF'
awing FA and DA we find that quarter-
or the octagon mitre, is 5 inches to the
nd that half-pitch, or square mitre, is 12
to the foot. From this, by the rule of
root, it will be found that the length of
on an 18-foot building for third-pitch is 10
nches.

may be put down as theoretically correct,
is not the method usually employed by

workmen, nor is it the method recommended to be used, as for all practical purposes, in lying out the length of a rafter and getting the bevels for pitch of one-third, it is better to take 8 inches on the tongue of the square and 12 inches on the blade, which will give the rise of the roof near enough for all practical purposes.

The term "pitch" as understood by the workman, does not relate exactly to the slope of the roof, but rather to the height of the ridge from the level of the plates, therefore, a building having a span of 30 feet from outside to outside, to be covered with a roof having a half-pitch, will have its peak 15 feet above the level of the wall plates. Among the learned quidnuncs, the pitch of a roof is not known by "ratios" or quarters, thirds or half-pitches. If we examine the leading dictionaries we learn that the pitch of a roof is expressed in angular measurements in parts of the span. It is also designated by the proportion which the rafters bear to the span, and what is known in some places as common pitch, the rafter is ¾ the length of the span. The so-called Gothic pitch is formed by having the rafter the length of the span, which, when in place, forms an equilateral triangle, as shown in Fig. 152. The Elizabethan or knife-edge pitch

formed by having the rafters longer than the span, as shown in Fig. 153. There are other definitions formed in dictionaries; for instance, we are told that the Grecian pitch produces a

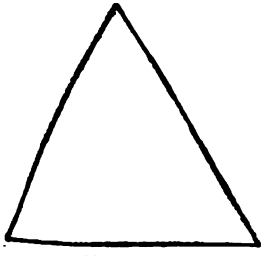


FIG. 152

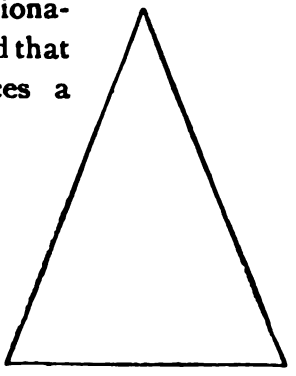


FIG. 153

roof the angle of which is from twelve to sixteen degrees with the horizontal, as at Fig. 154, and that the Roman pitch results in a roof the angle of which is from twenty-three to twenty-eight

FIG. 154

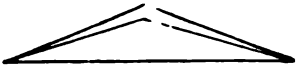


FIG. 155

degrees, as seen in Fig. 155. Another way of expressing "pitch" is based upon the length of the rafter in parts of the span. Thus, if the span is 30 feet, and the length of the rafter is 20 feet, the pitch would be said to be one-third pitch. From all this it is evident that, as yet, there is no generally accepted rule for defining

the "pitch" as relating to the length of the "rafter", either by "ratios" or otherwise. It is quite evident that the pitch of a roof, as now understood, relates rather to the rise than to any relation it has to the slope, therefore it is best to follow custom *most* generally accepted by the actual workman, and call a two-thirds pitch the one formed by raising the roof two-thirds above the level of the plates. This seems the most reasonable way, and will, sooner or later be universally adopted because of its eternal fitness and the readiness of being understood, as may be gathered from the following: Suppose we have a building having a 24-foot span to roof, a one-quarter pitch would be 6 feet rise, or 6 inches to a foot of run of rafter. The same run applies to all pitches; thus, 6 inches to 1 foot is one-quarter pitch; 8 inches to 1 foot is one-third pitch; 12 inches to 1 foot is one-half pitch, and 16 inches to 1 foot is two-thirds pitch, and so on. This is easily understood by the workman, and is as easily executed, if the operator understands how to use the steel square, and nearly every workman does nowadays. The method of defining the pitch of a roof by using degrees is troublesome, and not in keeping with modern progress, and will not work handily, as the

elation between the horizontal and the perpen-
icular is not easily defined, for the following
easons: Pitches of roofs are determined by a
actional part of the span, and by inches of rise
the foot of run of the rafter, and the reason
at a one-half pitch is an angle of 45° is because
e rafter happens to form a right angle, but
loes not prove that we must divide the 45°
gle to find the other pitches, but, even if it
, that would be no reason for using the terms
pitch of 45°, or a pitch of 26° 30" for a half-
ch or a quarter-pitch," as would be the case,
as shown by the di-
agram, Fig. 156, if
we adopted the
degree method in-
stead of the rea-
sonable one now in
use.

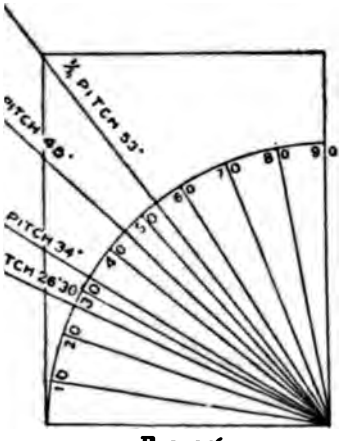


FIG. 156

There is no rea-
son, however, why
the workman
should not make
himself acquainted
h all the known methods of determining
ch", and the methods of laying out the work
ccordance with such methods. It is impossi-

ble for a workman to know too much regarding his calling.

On this question of pitch, I think it proper to give my readers as nearly as possible all sides, and to this end I have obtained permission from Mr. Woods to publish the following, which is from his pen: "The word pitch has reference to the rise given the common rafter in proportion to the span. Therefore by letting 12 on the tongue represent the run of the common rafter the figures on the blade will then represent the rise in proportion to its length (the blade), as 6 being one-fourth of 24 represents the quarter-

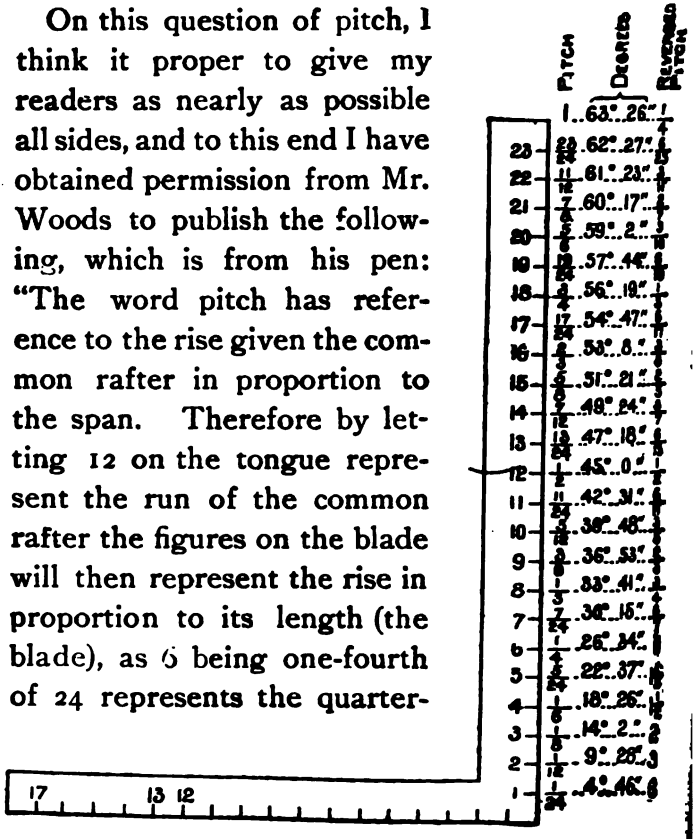


FIG. 157

pitch, 8 represents the ⅓ pitch, 12 the ½ pitch, etc. See illustration. Fig. 157."

For the corresponding hip or valley for the

octagon or square-cornered building substitute 13 and 17 on the tongue, respectively. However, neither are absolutely correct, but near enough for practical purposes.

The lengths taken diagonally from 12, 13 and 17 on tongue to the figures designating the rise on the blade represents the lengths of the above rafters for a one-foot run. Only three of the lengths out of the seventy-two are without fractions and they are for the common rafters, as follows: 12 to 5 = 13 inches, 12 to 9 = 15 inches and 12 to 16 = 20 inches. It is on the latter that the rule 6, 8 and 10, so generally used for squaring frame work, is founded. Of course, any of the other angles could be used for this purpose, but the above being without fractions are easy numbers to remember.

The length of the common rafter doubles its run or has a length equal its span when it has a rise of 60°, which taken on the square is 20.784 inches rise to the foot. The same occurs of the octagon hip when it has a rise of a fraction less than 23 inches, and that for the common hip at nearly 29½ inches rise to the foot.

In the illustration I also give the reversed pitches. That is, by letting the blade represent the run and the tongue the rise. The length of

the diagonal lines in that case becomes the length of the rafter for a one-foot rise to the inches in run taken on the blade.

The reader will notice that several of these pitches are transposed and are found in the first column, as follows: The 1 pitch is the same as the ¼ pitch when reversed. The ¾ same as ⅓. The ⅔ same as ⅜. The ½ remains unchanged. The low pitches in the first column become very steep when reversed. Thus, the $\frac{1}{12}$ pitch becomes 6 pitches or a rise of 12 feet to a 1-foot run. The $\frac{1}{12}$ pitch is equal to a rise of 6 feet to a 1-foot run, etc.

For the corresponding lengths of the hip or valley for the reversed pitches add $\frac{1}{17}$ and $\frac{1}{17}$ to the run of the common rafter for the octagon and right-angled corner respectively. In our illustration we also give the degree of pitch for the common rafter. To find the same for the reversed pitches, it is only necessary to subtract the degrees here given from 90°.

I may have to revert to the subject of "pitches" again, as there are still some points on the subject, from a workingman's point of view, that will bear further discussion.

Quite a graphic method of laying out a common rafter is shown at Fig. 158. This, it

l be seen, is the method described in the epart of this volume, with some additional

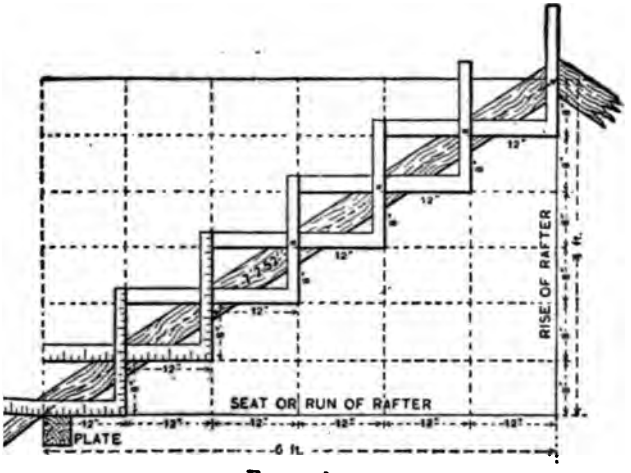


FIG. 158

planation. Here the rafter is shown in sition, with the square shown on each foot the run of the rafter; also the rise for each ot. The illustration shows a rise of 4 feet or inches in a run of 6 feet or 72 inches. The iare is applied upon the line representing the ter of the rafter, and shows the length from center of the ridge to the top of the plate. the conditions of the problem the rise of the er is 8 inches to every 12 inches of run; ordingly 12 of the blade is taken to 8 of the gue on the length of the rafter, as shown in

the diagram. Any other number of inches to the foot can be obtained in the same manner. Hip and valley rafters can be got in the same way, simply taking the rise in inches on the tongue and 17 inches on the blade, running the same number of times as for the straight rafter. The reader in making use of this plan should always remember to run a gauge as far down the rafter as notched. The measurements are made from the top corner of the plate. The example shown illustrates third pitch, as 8 and 12 are the figures used on the square. This illustration and explanation, I think, are presented in such a manner that any ordinary intellect can grasp it all.

SOMETHING ON HIP ROOFS

In referring again to hip roofs, I know I am on lines the young workman likes to follow—and many old ones as well—for in these days there is such a strong tendency among architects to cut up roofs into as many gables, hips, valleys, saddles, as can possibly be crowded in. This is a remnant of the Queen Anne fad of thirty years ago; a fad that has left us so many country houses with gables, towers and peaked corners, the best of which can be said of them is, that

re somewhat picturesque. As said before, tting of a hip or valley rafter is the same tting a common rafter for a building of ent dimensions with the difference that used as a hip or valley rafter, the top end have side as well as plumb bevels. In to make this , examine the shown at Fig. Here DB and how the seats es of the hips; if CB was d so as to run

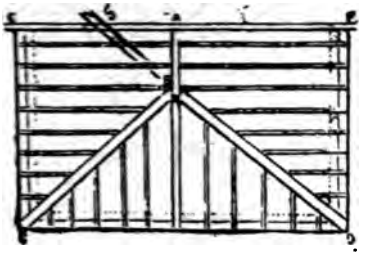


FIG. 159

e direction of S, then DBS would show a with its face towards C, thus showing that p rafter is an extended rafter made to meet in conditions. This plan shows besides the hips, common rafters, jacks and ridge, with projection over eaves. The line EAF, may represent a junction with another portion of the building. A side elevation of the roof is given at Fig. 160 showing hip, ridge, and common rafters in position.

FIG. 160

rder to give a clear idea of how a hip roof

should be laid down on plan, I exhil
following diagram, Fig. 161. Let BEXY

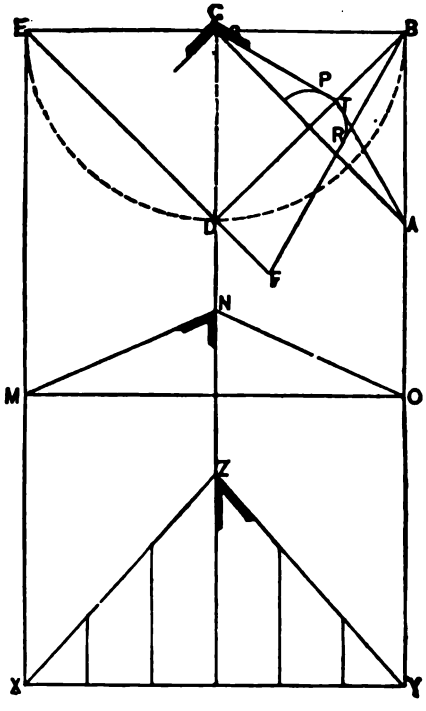


FIG. 161

sent the en
regular ro
ing a ridge
the center.
DC on th
equal to h
width EB
the angle
will be a ri
gle. Dra
line, as AC,
angles to D
D. Set
height of t
as DF an
FB, which
the length
hip rafter
one foot

compasses in the center of the line A
with the other describe a semicircle, t
the line FB in the point R. In other wo
semicircle to be drawn is of such a radiu
make it tangent to the line FB in the
From the point T, at which the semicir

ıe line DB, draw TA and TC, which will give ıe form of the backing of the hip rafter.

To find the length of the jack rafters and heir bevels to fit the hip rafter, make the hip QX and ZY equal to the hip line BF, and square up the jack rafters, as seen in the plan, until they meet the hip, which operation will give the length of each jack rafter for the ends and also for the sides of the roof. It will be readily perceived that the bevel S is the side bevel of the jack rafters, and also the bevel to miter the upper ends of the truss. The bevel N, which is the down bevel of the common rafters, will also be the down bevel of the jack rafters at the hips. This is but one of the methods by which a hip roof may be laid out, without the aid of the square. There are many other methods, some of which I will illustrate and describe in Vol. II.

Another diagram shown at Fig. 162, exhibits roof that has an acute and an obtuse corner as well as corners at right angles. The hips and ıe method for obtaining the backing for them re shown quite clearly and do not require ırther explanation.

An old, but very reliable method of finding e lines and bevels for backing a hip, is shown Fig. 163, where ABCD is the plan of the roof;

draw the diagonals AC and BD, over which hip

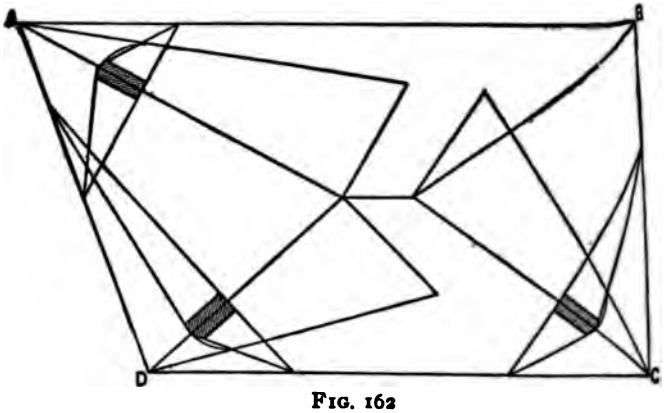


FIG. 162

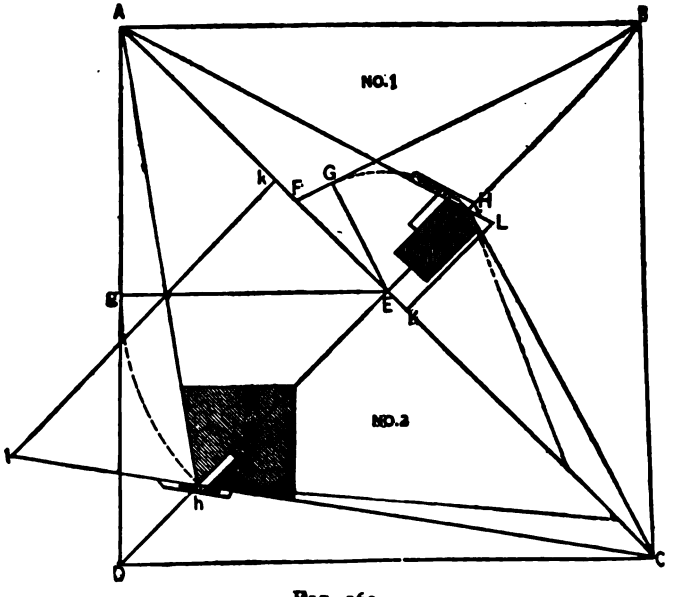


FIG. 163

rafters rest when in position. On the line AC for pitch No. 1, make EF equal to height of roof; connect FB, which is length of hip rafters; make EG perpendicular to FB. On line EB make EH equal to EG; connect AHC. The enclosed triangle will be a section of roof formed by a plane cutting from line AC at right angles with hip rafter. The shaded figure at H shows the position of hip rafter and manner of setting bevels. To prove the rule, make AK equal to length of hip rafter, and KL equal to height of pitch; connect AL. The angle at L being equal to angle at H, proves the rule to be correct on a flat pitch.

On the lower side of line AC, pitch No. 2, I have made the height equal to EA. AD is the length of hip. E*k* is equal to E*g*, and C*k*A is section of roof as before. C*k* is length of hip; *lk* is height of pitch, the angles at *l* and *k* being equal as before. The lines can be obtained with the square as follows; the tongue of square represent the side of the rafter—the blade for the base and the straight-edge the top of the rafter. Another method of backing a hip rafter is shown at Fig. 164. First lay off cut, and AB the line of the plumb cut, from A draw AC perpendicular to AB. Lay off AE, making it

equal to one-half the thickness of the hip. Through E draw GF parallel to the top of the

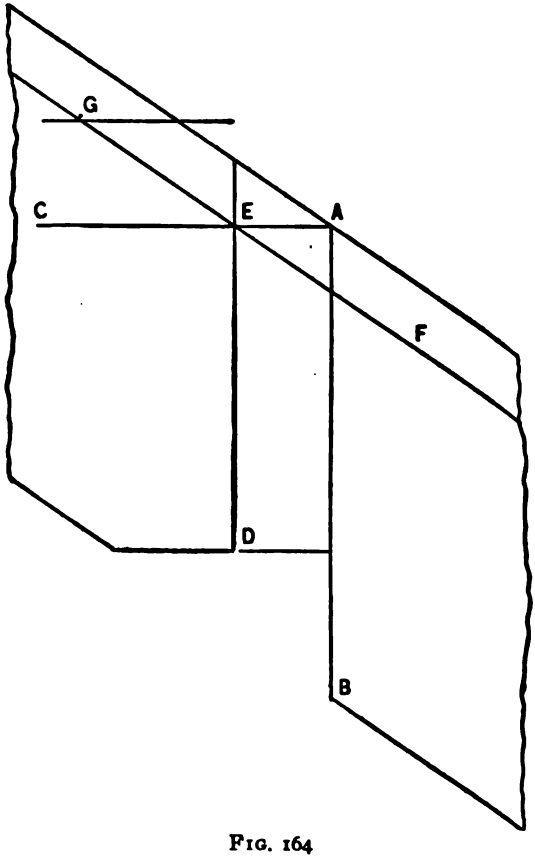


FIG. 164

rafter, and GF is the amount to be taken off in order to make the proper backing, working, of course, to the center of the hip. This is on the

position that the seat of the hip is at an gle of 45 degrees with the side of the building. r octagonal or other such roofs in place of ying off from A one-half the thickness of the ip, draw DE parallel to AB, letting D be the oint where the plate of the building intersects he side of the hip.

A very good method of obtaining the lengths of jack rafters was sent to *Carpentry and Building* some time ago by a correspondent, and I think worthy of a place in this work, as it is quite a time-saver.

In this case the common rafter strikes the ridge at the point of the hip. Suppose the common rafter, Fig. 165, is set off 2 inches from the point of the hip, the rafters being 24 inches on centers and half-pitch, we have 24 – 2 = 16.

Take 16 and 16 on the square, which will give he length of the longest jack on the short side. Thirty-four inches off gives the next jack, and o on. The sketch shows so clearly what is neant that further description would seem to be innecessary.

The methods given herewith for obtaining the measurements and bevels for hips, valleys, jacknd common rafters may be considered as reliable. We suppose the hips and valleys are

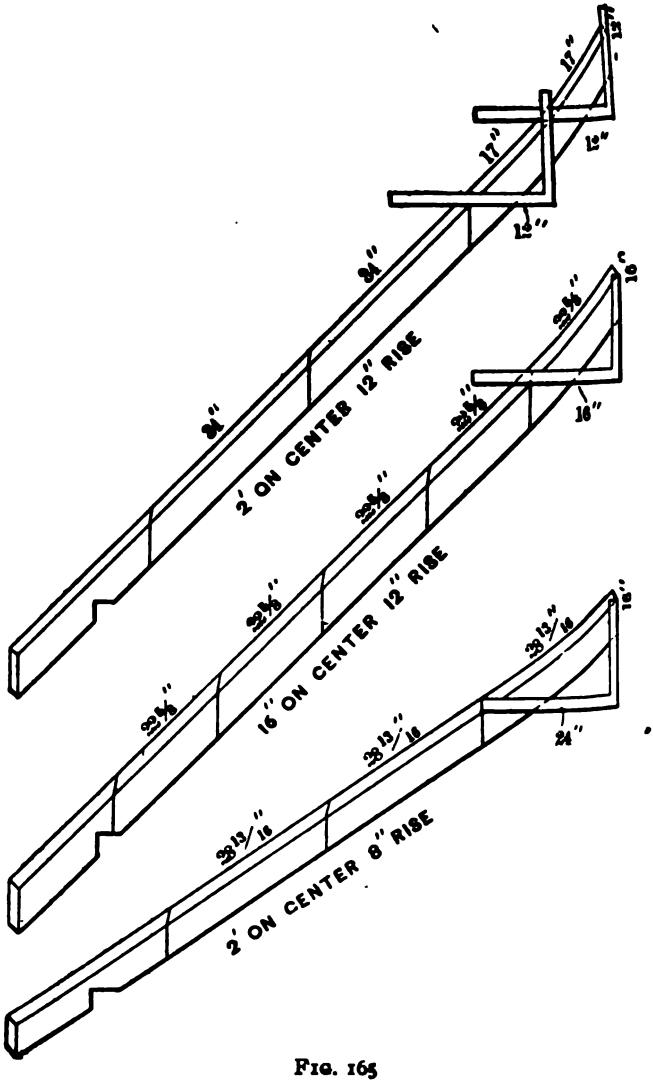

12"
17"
12"
17"
12"
24"
2' ON CENTER 12" RISE
16"
16" ON CENTER 12" RISE
24"
2' ON CENTER 8" RISE

FIG. 165

ıngle of 45° with the eaves. Suppose the be one-third pitch, or, in other words, to inches rise to the foot; then take 8 inches tongue of the square and 12 inches on ıde, and apply to the rafter as shown in

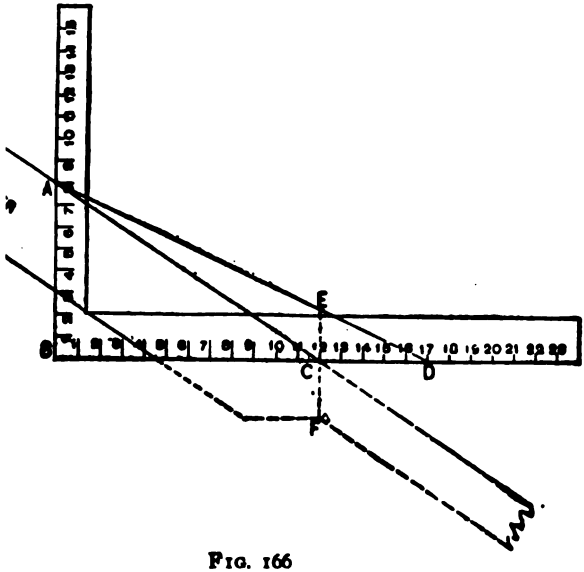


Fig. 166

6. Take this measure as many times as .re feet in half the width of the building. 'ill be the length of the common rafter t the projection. This is to be added as ed by the dotted lines. The bevel for the the rafter is indicated at A, and for the the rafter at C.

To get the length of hip and valley rafters change the measure on the blade of the square from 12 to 17 inches, as shown by ABD in Fig. 166, and take this measure the same number of times as for common rafters. The down bevel for top of rafter is at A, and for heel is at D. Take the measure of the hip rafter to the point of miter at the top end when mitered to fit ridge board. Half of the thickness of the ridge board is to be taken off both hip, valley, and common rafter measurements. This will be better under-

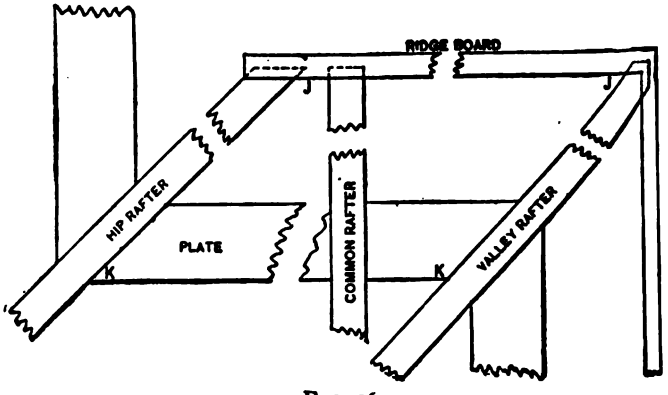


FIG. 167

stood by examining JK of Fig. 167, of the diagrams. The plumb-line CF, Fig. 166, stands plumb over the face of plate and must be the same length in hip and valley rafters as in common rafters. This makes the projecting

art of hip and valley rafters wider than of ommon rafters.

To get the length of the jack rafters apply the quare the same as for common rafters, as ndicated at ABC, Fig. 166, once for every foot. They are placed on the plate from the foot of hip rafter or corner of building. Time may be be saved by marking the foot measurements on the pattern of common rafters and transferring them, as may be required, to the various lengths of jack rafters. The half-thickness of ridge board of hip or valley rafters, as the case may be, is to be taken from these measurements as required. The down and foot bevels are the same as in the common rafters. The top bevel is obtained by taking 12 inches of the base BC on the tongue, and 14½ inches (nearly) of hypothenuse on the blade AC, Fig. 168, and applying it as shown by GHI of Fig. 166. The top bevel of the jack rafter is at I, while G gives the face bevel for sheeting. Eight, and 14½ inches taken on the square in the same manner, marking out 8 inches, gives the edge bevel of the sheeting. The top bevel of hip and valley rafters is obtained in the same manner as for jack rafters, only it is treated as a jack rafter in a flatter-pitch roof. From this it may be laid

down as a rule that the base and hypothenuse of a right-angle triangle forming the pitch of any

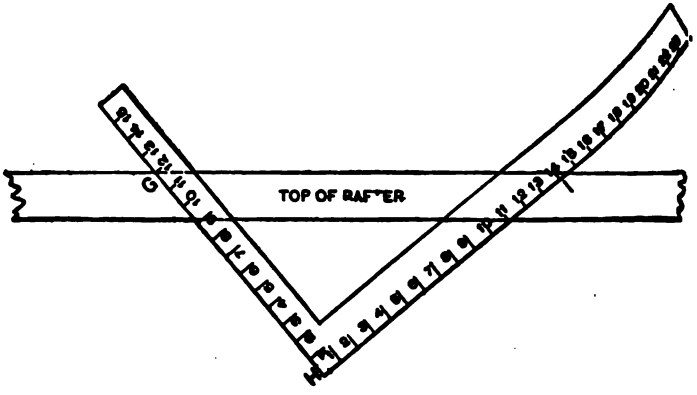


FIG. 168

roof or rafter taken in any proportion on the tongue and blade of a square, and applied as shown by GHI of Fig. 168, will give the top bevel of hip, valley and jack rafter, as also the bevel of the hip and valley shingles and for mitering a raking frieze. In laying out for cutting miters on purlins for a hip roof, the following method is a very good one: Let ABCD, Fig. 169, be the purlin, E, the common rafter drawn to correct pitch, FGH, the plan of the angle of the building, and GI, the plan of the hip. From the angles, AD, and C, of the purlin, draw lines AJDKCL, parallel to FG; make KN, equal to the depth of purlin and

equal to the thickness of same; draw NO, MP, parallel to FG. From the points where nes from A and : the plan of the lraw JP and LQ 'e from FG; join and KP. The : of RKQ, will ıe level for the or side cut, and ngle MPK, will ıe bevel for the .cross the edge. :tting out, it is able to mark the ı as near full ıs possible, to insure the bevels being accu·

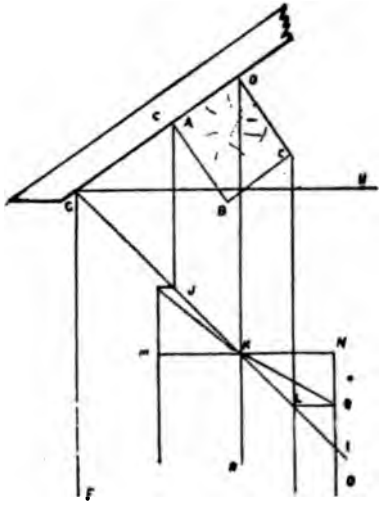


FIG. 169

quick way of finding purlin lines by the 'e is given herewith: for the top and down ls of purlins in a roof which rise 16 inches inches run use the following figures: For ide bevels take 16 inches on the tongue and ches on the blade of the square and the ue will give the bevel required. For the)evel take 12 inches on the tongue and 20 :s on the blade of the square and the tongue

will give the required bevel. The bevels for 8-inch rise and 12-inch run are as follows: For the top side take 12 inches on the tongue and 14⅜ inches on the blade of the square and the tongue will give the required bevel. For the side bevel take 8 inches on the tongue and 14⅜ inches on the blade of the square and the tongue will give the required bevel.

OCTAGON FRAME WORK

The following modern methods of working out octagon frame work, have been gathered from many sources, chiefly from the actual workings of the men who themselves have either designed the methods or executed the work; and where I have been unable to examine the work, I have in my own workshop tested the methods, either by making models or laying out the lines and proving their correctness.

The secrets of the octagon, or in fact of all workable polygons, are perhaps better exposed to the light of day in "Wood's Key to the Steel Square," than it is possible to show in these pages under the conditions to which ordinary book-making is limited. However, I deem it just to my readers to give a short chapter in this volume on the subject of octagon roofs, leaving

for the following volume, a more extended discussion of the subject. Let the plan and

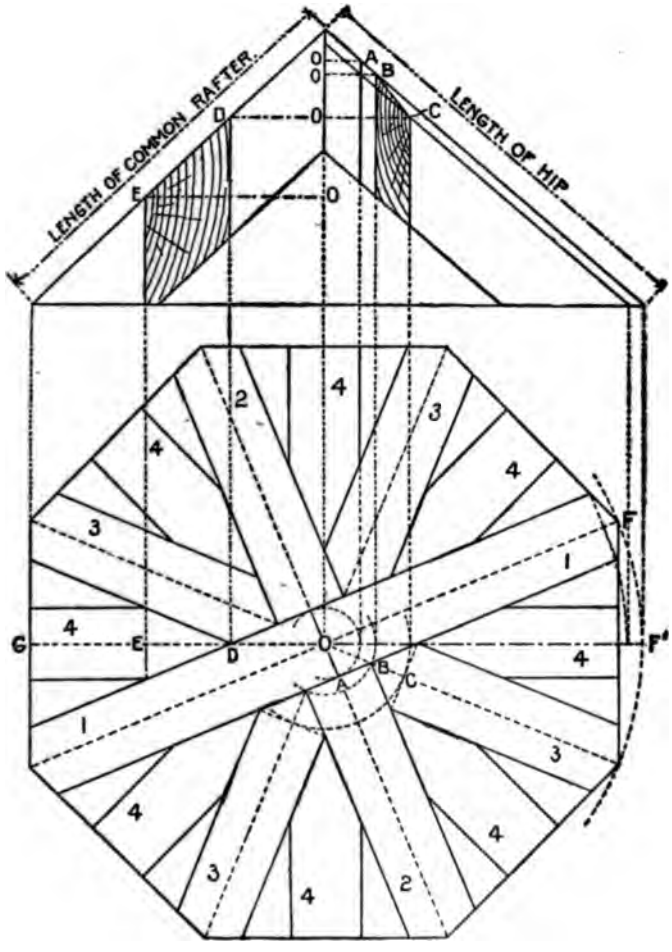


FIG. 170

elevation of an octagon roof showing the runs of the common and hip rafters as exhibited in Fig. 170, be the ground work of this problem. The runs are reckoned from the outer edge of the plates to the center, as GO for the common rafter and OF for the hip, but since all of the rafters do not run to the center there must necessarily be a deduction from the runs, as given above.

In the plan it will be seen that only one set of the hips (No. 1), meet at the center. Set No. 2 lacks the thickness of No. 1 of coming together, or an amount equal to OA taken from the run of each rafter. The next two sets, No. 3, are of the same length, and the deduction for this is equal to OB plus BC to obtain the plumb cut for the side bevel. The run of the common rafter, No. 4, being GO the deduction from which is equal to DO plus ED to obtain the plumb cut for the side bevel.

Now, referring to the elevation, the above reference letters are used for like measurements, showing the proper deductions to be made to obtain the lengths for the different rafters by simply squaring back from the plumb cut.

The run and rise taken on the square

regulates the seat and plumb cuts, but the above deductions remain the same for any pitched roof.

In laying out a plan of an octagon figure, it is first necessary to understand how this may be done quickly and correctly. One of the simplest methods of forming the figure is shown at Fig. 171, where the corners of the square are used as centers, and the center A of the square for radius. Parts of a circle are then drawn and continued until the boundary lines are cut. At the points found draw diagonal lines across the corner as shown, and the figure will be a complete octagon, having all its sides of equal length.

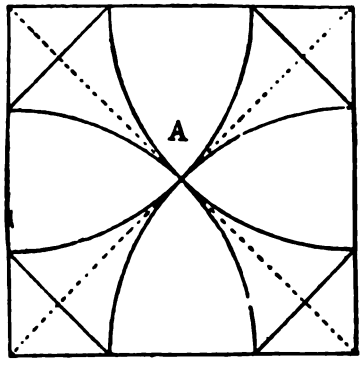


FIG. 171

To get the cut of miter of the angles we fall back on the steel square and take the figures 12 and 5 which gives us the correct cut very nearly, as shown at Fig. 172. It is unnecessary here to explain why these figures give the desired angle, as that will be talked over again. However, it may not be amiss to hastily glance at them *en*

passant. A line from 12 on the tongue and

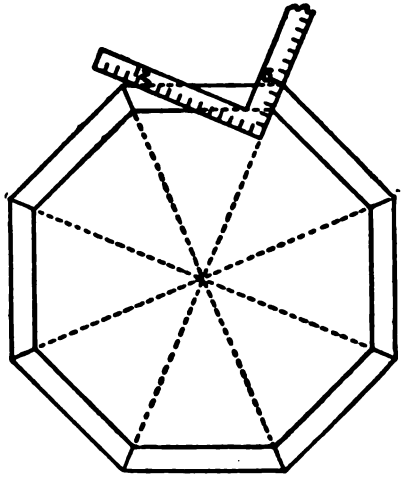


FIG. 172

crossing at 5 on the blade forms an angle which

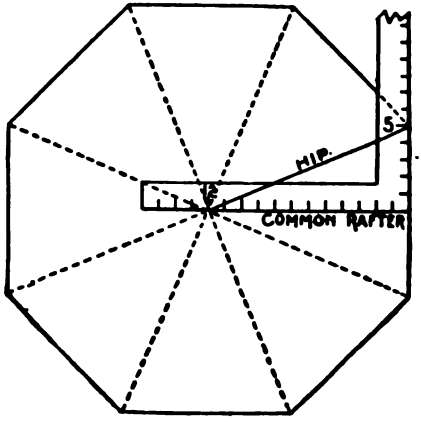


FIG. 173

e same as that formed by the runs of the non and hip rafters of an octagon roof and of which is represented in Fig. 173.

e also find that this line diverges from the ue 5 inches in a 1-foot run. Hence the side n octagon 1 foot in diameter must be 5 :s (see Fig. 174) or $\frac{5}{12}$ its diameter. This ortion always exists whether it be inches,

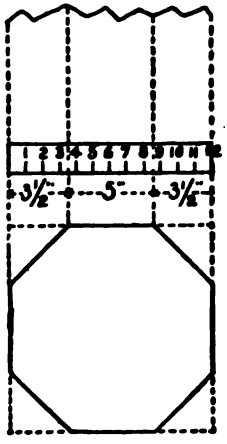


Fig. 174

Fig. 175

or yards. Thus the side of an octagon 1 in diameter would be $\frac{5}{12}$ of an inch. A 6-in. ıeter would be 6 × 5.12 = 30.12 or 2½ inches, 175.

ɜain, from 12 to 5 measures exactly 12 es, a gain of 1 inch to 1 foot run of the mon rafter. Therefore the run of an

octagon hip is $\frac{1}{8}$ longer than that of the common rafter.

Now, let us apply the above to the full size diagram, as shown at Fig. 176.

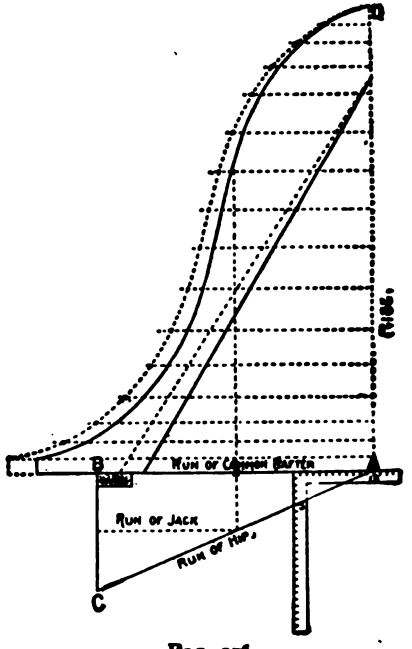


FIG. 176

Draw BA. Place the square as shown, and draw line AC, and square down from B to C. AB is the run of the common rafter. AC is the run of the hip, and is $\frac{1}{8}$ longer than AB; BC is equal to one-half the length of the plate, and is $\frac{5}{8}$ the length of AB. The whole figure bounded

AB and C, is 1.16 of the plan, and is all that is essary to draw.

ow, lay off the rise AB, and the desired re for the common rafter, and draw any ıber of lines parallel with AB, from the to a few inches beyond the curve of the mon rafter. Now, measure these lines from to curve, and for each foot and fraction of : add to same line as many inches and lfths of inches as there are feet and inches in gth.

ı other words, if a line is 6 feet and 9 inches g, add to its length 6.9, 12 inches and make a

After all lines have been thus measured, an off-hand curve through the dots, and the esponding hip is determined.

he jack being a part of the common rafter, shape is easily found by laying off the run squaring up as shown.

is thought better to run only the hips to er and by using an octagon ped block or pole set with the s, so that the hip will rest nst it squarely so as to get d nailing, as shown in Fig. besides, letting the block

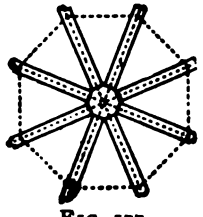


FIG. 177

extend above roof furnishes an excellent stay for a finial.

The cuts are all contained in figure bounded by ABC and D, but are not shown in this diagram. This subject will be discussed again, when describing the framing of octagon towers and spires.

PRACTICAL TREATISE ON THE STEEL SQUARE.

VOL. I.

The student will be expected to read carefully these papers before doing any work. His name and address will require to be given on each page. He will be expected to write up the questions in a neat and intelligent manner, using his own language and style, representing the answers in such a manner as will be intelligible—make all drawings as clear as possible, and wherever it can be done render them in India ink. Let each answer be original, do not copy either from the instruction paper nor from any other source. The paper used may be of any kind, provided that it is clean and durable. Do not attempt an answer until you have thoroughly grasped the subject.

QUESTIONS.

1. Describe what is "the face," "the back," "the body," and "the tongue" respectively of the steel square.

2. In "Rule for framing," what does the first line of figures give?

3. What does the second line of figures give?

4. What does the third line of figures give?

5. What does the fourth line of figures give?
6. What does the fifth line of figures give?
7. What does the sixth line of figures give?
8. What does the seventh line of figures give?
9. If a roof is raised 8 inches to the foot, what pitch is it called?
10. If a building is 16 feet wide, what will be the run of common rafter, and the figures used to find the length.
11. What figures will be used to obtain the bottom and top cuts of common rafter.
12. Upon what line of the "square" and what figures will be used to find the correct length of hip or valley rafter?
13. What figures on second line of "square" will give top and bottom cuts for hip or valley rafters?
14. Upon what line and what figures will be used to get length of first jack rafter and the difference of the others spaced 16 inches on centers, and give example?
15. Upon what line and what figures will be used to get length of first jack rafter, and the difference of the others spaced 2 feet on centers, and give example?
16. Upon what line and what figures will be used to get side cut of jacks against hip or valley rafter?
17. Upon what line and what figures will be used to give side cut of hip or valley rafter after ridgeboard or deck?

Upon what line and what figures give the
f sheathing and shingles in valley or hip?

What other "cuts" can be obtained from
igures on the "square" that give side cuts
cks?

What other "cuts" can be obtained from
figures on the "square" that give cuts of
hing in valley or hip?

Describe how to obtain the bottom and
uts of hip or valley rafter.

Describe how to obtain the bottom and
uts of common rafters and jack rafters.

Describe what is meant by the "octagon
ght square scale" and give illustrative sketch.

Explain what is meant by the "Brace
ure" and give example.

Give a few suggestions as to how to take
of the "square."

Describe the "diagonal scale" on the steel
re, and give a sketch of same.

Describe what is meant by "the run of a
r."

Describe what is meant by "the rise of a
"

Describe what is meant by "the pitch of a
"

How may the cuts or angles of a rafter be
ned by application of the "square" and give
h illustrating.

31. Describe "the rafter table" on the steel square.

32. Describe how to find the length of rafter for a roof with 1/6th pitch and having a run of 12 feet.

33. Describe how to find the length of a rafter for a roof ½ pitch and a run of 12 feet.

34. If the run is 25 feet how would the length of rafter be obtained?

35. When the "run" is in inches, how is the rafter table to be read?

36. If the "run" is 12 feet 4 inches on a ½ pitch roof, show how rafter length may be obtained.

37. Explain what is meant by the "Essex Board Measure Rule" and give illustrative sketch.

38. Give description of the "Bridge Builders' Square."

39. Give description of the "Machinists' Square."

40. Give description of the "Bench Square."

41. Give description of the "Crenelated Square."

42. Give description of "Combination tool" consisting of slotted square and rules, and the uses to which it can be applied.

43. Give description of the "Adjustable try steel Square."

44. Give description of "Combination Square Miter and Inclinometer."

45. Give description of "Starrett's Carpenters' Square."

46. Explain the use of "Starrett's Stair Gauge Fixtures."

47. Give description of the "Key to the Steel Square."

48. Explain how to find the lengths and cuts for the ½ pitch.

49. Explain how to find the corresponding octagon hip and the common hip or valley.

50. Explain how to find the common difference in the length of jacks.

51. Explain how to find the common difference for the octagon jack.

52. Explain how to find the side cut of the jack.

53. Explain how to find the "side cut of the octagon jack."

54. Explain how to find the "side cut of the hip or valley."

55. Explain how to find the "Backing of the hip."

56. Explain what the figures in the two circles of the "Key" represent.

57. Explain how to frame a roof with 30° pitch.

58. Explain how to find "common rafter" for same.

59. Explain how to find "octagon hip."

60. Explain how to find "hip or valley."

61. Explain how to find "side cut of jack."

62. Explain how to find "side cut of octagon jack."

63. Explain how to find "side cut of hip or valley."

64. Explain how to frame a roof with 60° pitch.

65. Explain how to find the miter for any regular polygon.

66. Explain how to find the miter for a "nonagon" (9 sides).

67. Show how to frame timbers at any degree of pitch.

68. Give description of "Reissmann's Rafter and Polygon Gauge" and its uses.

69. Give description of "double-slotted fence" in connection with steel square.

70. Give description of "single-slotted fence" in connection with steel square.

71. Give description and sketch showing application of "square and fence" in laying out a stair string.

72. Give description and sketch showing application of "square and fence" in laying out rafters to a line.

73. Give description and sketch showing how to lay off a rafter without making use of "fence."

74. Give description and sketch showing metal fence or stair gauge.

75. Give description and sketch showing "fence and slotted square."

76. Give description and sketch showing ap-

plication of "square and fence" in laying out a "housed string."

77. Give description and show by sketches how the "square" can be used for getting the lengths and bevels for braces and regular and irregular runs.

78. What does the length of any brace simply represent, and give an example?

79. Describe how "the octagonal" scale may be applied in dressing a stick 10 inches square to an octagonal shape.

80. Describe how to find the number of inches to take on blade and tongue for a given rise and run of a brace.

81. Describe how to find a circle equal in area to two or more circles.

82. When 3 points not in a straight line are given, show how to find the center of a circle which will pass through them.

83. Describe how to find the center of a circle with a "square."

84. Describe how to find the side of a square of half the area of a given square.

85. Describe how to lay off angles of 60° and 30°.

86. Describe how to lay off an angle of 45°.

87. The hypothenuse and one side of a right-angled triangle being given, describe how to find the other, or two sides being given show how to find the hypothenuse.

88. Describe how to lay off an octagon on a given side.

89. Show how to obtain the length and bevels for an "octagon Hip-rafter."

90. Describe how to make a square stick octagonal.

91. Describe how to find an octagon when the side of the square is given.

92. When the side of the octagon is given describe how to find the square width.

93. When the square width is given, describe how to find the diagonal.

94. Describe how to find the bevels and width of sides and ends of a square hopper.

95. Describe how to find the "Backing of the Hip rafters."

96. Describe how to find the lengths and bevels of Hip rafters.

97. Describe how to find the lengths of the "Jack rafters."

98. Describe how to find "the lengths of Jack rafters on the end."

99. Describe how to find the first, the second, third and fourth pairs of hip rafters and middle jack rafter of an octagon roof.

100. Describe how to find the first, second and third pairs of hips, also the backing of the hips of an octagonal roof.

101. Give sketch of the "straining beam," the "brace" and the "tie-beam" of a roof, and describe

w to find bevel of the upper end of the brace ıere it butts against the straining beam.

102. Describe how the angle made between :ace and straining beam is bisected.

103. Give description how "plain stairs" are onstructed.

104. Describe how to find the "cuts and bev-ɛls" for a hexagonal hopper.

105. Describe how to find the "cuts and bevels" for an octagonal hopper.

106. Describe and show by sketch how to construct a "conveyor" for a flour mill, with the following dimensions: Diameter of shaft 5 inches, length 14 feet, pitch of flights or screw 7 inches.

107. Describe and show by sketch how to construct a "conveyor" with an octagonal shaft.

108. Describe and show by sketch how to find the largest rectangular stick that can be cut from a round log.

109. Give description of how a "square" may ɔe tested.

110. Give description of what is generally known as "the American Steel square."

111. Give an example of how to use the steel square to cut a brace to support a beam or bracket.

112. Give description and sketch how to find ıe run of a hip, the length of the jack rafters, ıd the backing of hip.

113. Fig. 46, vol. 4, is a roof having three ga-es, each being a different pitch, the two valleys :ing unequal as regards run. The ridge is 8 feet

above the level or plate. Describe how to find the rafters, hip rafters, jack rafters, and all the bevels and cuts for the roof.

114. Describe how to make a step-ladder to reach a landing 8 feet high and to slope to a convenient point 4 feet 6 inches back.

115. Give description and sketch showing the method of testing the exterior angle of a steel square.

116. Give description and sketch showing how to compare the exterior angle of a steel square, with its interior angle.

117. Give description and the figures which are as large as possible, so as to reduce the possible error in measurement to the smallest possible dimensions.

118. Give description and sketch showing how by steel square to obtain the right angle or square miter, the octagon miter, and the hexagon miter.

119. Give description and sketch showing how the square may be employed to describe a circle.

120. Give description and sketch showing a handy method for determining the dimensions of the largest rectangle that can be drawn in a given circle.

121. Give an example of how "the pitch" of a roof is described.

122. Give description and sketch showing how the relationship of certain divisions of the circle to different figures on the square is indicated, or

n other words, how degrees may be obtained with the square.

123. Give description and sketch showing how to lay off an octagon on the end of a timber.

124. Show by use of the square how to miter a pentagon.

125. Show by sketch and description how to lay off "a hexagon" from a square timber.

126. Show by sketch and description how to find center of circle with the square.

127. Show by description and sketch a rapid method of dividing anything into several equal parts, by use of the square.

128. Show by sketch and description a good method of cutting bridging by use of the square.

129. Give description and sketch how to make an ellipse for a three-foot opening, one foot high, by use of square.

130. Give description and sketch how to make an oval by use of square.

131. Give description and sketch showing how to bend a board for a circle, if the given length is ? feet.

132. Give description and sketch showing how o find the number of courses of shingles for a oof.

133. Give description and sketch showing how o cut a miter box by aid of the square for raking ıouldings.

134. Give description and sketch showing how y means of the steel square to determine the

proper figures to use for making the cuts on a "third pitch" roof.

135. Give description and sketch showing how to make a miter box with cuts, by use of the square.

136. Give description and sketches showing the method how to cut the members of a raking cornice where the angle is 45°, by use of the square.

137. Give description and sketch showing how to find a line forming equal angles with two converging lines, by use of the square.

138. Give description and sketch showing how the sectional part of a circular frame or wheel may be obtained by the aid of the square.

139. Give description how to make a frame with eight equal parts, by use of the square.

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STEEL SQUARE

PART II

PREFACE

In preparing this second volume of practical work for steel square users, it was imperative I should, in some measure, give examples and rules that were somewhat similar to a number that appeared in the first volume; though on close comparison it will be found that the similarity is apparent only, as different solutions of similar problems are rendered.

Perhaps it is unnecessary to mention this, as the expert workman will recognize the difference at once; but, in order to make explanation beforehand to the many thousands of readers, who, while not being experts now in the use of the square, intend to become so as quickly as possible, I thought it better to mention the matter in this preface.

The purchaser of this volume will find many things in it that are original, and many more that have been culled from the best work of experts and which have appeared in some one or other of the great number of trade journals that have been published in this country, in Eng-

land and Australia, during the last twenty-five years. As before stated, there are a number of things original in the volume that have never before been published, some of my own and some that have been furnished by experts. I have made it my business to write to every person—at home and abroad—that I could hear of or read of, who had made a study of the steel square, asking for anything they might have that was new and useful on the subject, and telling them I was preparing a new and exhaustive work on "The Steel Square." While all did not respond, I may state that over 75 per cent of those written to did; and while the great majority had nothing to offer, a great many sent me "cuttings" from journals, on the subject, with diagrams and suggestions. Many, of course, of the problems sent me I could not make use of for obvious reasons, while several gentlemen sent me—for publication—a number of valuable problems and solutions which I have embodied in the work and all the writers, without exception, wished me "God speed" in the work I had undertaken.

It is now in order for me to publicly thank those who have so kindly aided me in getting together so much valuable material for the

workman as will be found between the covers of these two volumes, and I am sure my readers feel as I do in the matter.

Among those who might be named as having aided me materially, I may mention Mr. Woods, Mr. Reissman, Mr. Stoddard, and Mr. Penrose of Trafford Park, England, and Mr. Joseph Wilcox of Sidney, Australia, to whom I tender special thanks.

In conclusion, I may add, it is the intention of the publishers, should any new thing arise in connection with the steel square and its applications, to have the same embodied in the present volumes, or issue a supplementary volume if necessary.

If by these volumes I have been instrumental in aiding and assisting the operative workman to earn a little more wages than formerly he received, or have helped him to better his condition in any way, it will be a gratification and pleasure to me, and will, in some measure, repay me for all the effort I have expended in bringing together the matter contained in them.

FRED T. HODGSON.

Collingwood, Ont.,

PREFACE TO SECOND EDITION.

VOLUME II.

In this volume, as in the previous one, there are introduced some new features which I feel convinced will prove very acceptable to the practical student and well repay him for any extra trouble in reading or extra cost in procuring. A second preface to this volume, further than a simple announcement of its existence as a second edition of Vol. II of "The Steel Square and Its Uses," would seem an unnecessary labor, as the long preface in the volume of the first edition covers the entire ground, and, as a rule, the operative workman does not take much stock in a long-winded preamble. It is "meat," not preliminaries, the active workman looks for, and in this volume he will find plenty of the former and as few as possible of the latter.

I am convinced in my own mind, that the two volumes of this edition offer to the reader nearly double the amount of good, honest and useful material, than can be found in any other similar work. It is not padded with fancy solutions of useless problems, as every example offered is a tried one, and one likely to confront the workman at any hour of the day, and it is to this quality that the immense sale of this work may be attributed. While it is hardly fair to expect for this edition, the same gratifying results that followed the first, I feel satisfied the publishers, as well as myself, will have no reason to regret the issuing of this second enlarged and improved edition.

FRED. T. HODGSON.

Collingwood,

ANOTHER STEEL SQUARE

Since I wrote up a description of the various squares in the first volume of this work. I have been favored by a correspondent with the following description of a square which is the invention of a man in Augusta, Maine. I have not seen the square, nor have I seen a good illustration of it, but my correspondent says of it, "It is an ingenious tool for framing and can be adjusted so that work may be rapidly and accurately laid out, and it is capable of adaptation to all classes of buildings where wooden frames are used. I have used one for a number of years, and

find it quite handy for all kinds of work where timber is employed." The description sent is as follows: The body of the square has two tongues arranged upon it at right angles. Three bars are so secured to the tongues that by loosening set-screws at the ends they may be placed at any points desired, the bolts sliding in slots cut in the tongues. One of these bars has a slot cut in it the greater part of its length, on which two gauge blocks are secured by thumb-screws, and by which they may be slid back and forth and adjusted in any position desired. To the body of the tool, on one side, is secured a gauge, also capable of adjustment by means of screws. A bar, which is secured to one of the tongues and to the slotted cross-bar, is used in framing roof timbers and the like where diagonals are to be cut.

It will be impossible to explain all the ways in which the tool may be used. In laying out mortises and tenons on timber, the gauge on one side is placed so that the inner edge of the body of the square will come at the outer edge of the mortise and there secured. A bar is then adjusted so that the space between it and the body will be the width of the mortise. For single work this is all that is necessary for mark-

ing the sides of the mortises and tenons. For double work the second mortise is made by the adjustment of the other two bars, so that all change of the tool or liability to error is avoided. To mark the ends of mortises and tenons, the end gauge is adjusted at the right distance from the tongue lying parallel with it, the tool moved along on the inside of the gauge, and outside of the tongue the marking is complete. For framing roof timbers the bar for this purpose is adjusted at the desired angle, and by this the head and foot of rafters or braces can be marked, without changing the tool, the marks for the pitch of roof being put upon the slotted cross-bar and end tongue. The two small gauges are especially designed for use in cutting gains for shelving, and being adjusted at the proper places on the cross-piece and secured, proper measurement will be given.

As I stated before, I have not seen this square and am obliged to take the foregoing as being correct, but it seems to me that if the square is as useful as outlined it ought to be better known, but, having inquired at several large hardware houses regarding it, I find it entirely unknown among dealers. If any of my readers know anything of this square, as to its usefulness, price,

where it may be obtained, and will advise the publishers of this work, I will see to it that mention of it is made at greater length in future editions.

COLOR OF SQUARES

It is only a few years ago since any changes were made on the surface of squares. An old square that has been in my possession for fifty years and upwards had originally a polished steel surface, but to-day it is oxidized and covered with a coating that protects it from rust and from the weather. This happens to all polished steel squares if kept from getting wet or soiled with moist fingers. This condition, however, tends to render the figures and markings less legible; indeed, in many cases the figures and lines become almost invisible, a very great objection, for I have known some very serious cases where the figures have been mistaken and timbers cut too long or too short in consequence of the mistake.

A polished square should never be rubbed with emery paper or other gritty substance. While such rubbing may make the sides of the square look bright and "tidy," it is sure to injure the square, efface some of the figures and markings, and leave the surface more susceptible to rust.

little neat oil applied once in a while and rubbed with a soft rag is the best way to treat a polished square.

Since nickel-plating came in use, many squares are so treated, and this has many advantages, as under ordinary circumstances there will be no rusting and the square will always be bright and "tidy" looking. Under a bright sun it is often difficult to read the figures or find the lines required, and, if the tool is exposed to the sun's rays for a short time, it will become so hot as to preclude handling. A careful workman, however, will not allow his square—or any of his tools, for that matter—to be exposed to the sun for any length of time, as a two-foot blade often expands as much as one-eighth of an inch in length, when made hot—a condition the good workman cannot allow.

Squares electroplated with copper, in my opinion, are much better than either polished steel or nickel-plated ones. The copper color is not so severe on the eyes, and the shadows cast by the cuttings in the figures and markings bring up the figures almost in relief, so that they are readily seen. Age gives a copper-plated square a fine antique color which is restful to the eye and a protection to the square.

If the square is allowed to oxidize, and is then polished on the surface, we get a fine copper finish on the tool with dark oxidized figures and markings.

Best of all is the blued or what may be termed the "gun metal" square. These squares are oxidized or blued by some process unknown to me, and the figures and lines are filled in with some kind of white enamel, that brings them out in great shape. A very handsome blued and enameled crenelated square was sent me for examination by The Peck, Stow and Wilcox Company, of Southington, Conn., which lies before me as I write; and it seems to me that this method of bluing, and white-enameling the figures, is one of the greatest improvements made on the square for many years. To keep the copper, nickel-plated or blued squares in nice order, they should be rubbed over once in a while with good machine oil applied with a soft rag By this simple process a square may be kept new in appearance for a long period of years.

These few hints on the qualities of squares and their care will, doubtless, prove of value to my readers.

SOME ODD PROBLEMS

The workman often is confronted with very curious problems, and is as often put to his wits' end to solve them. Here is a problem and its solution that will prove interesting, though it is not likely to be met very often:

Suppose a box twelve inches square to be set

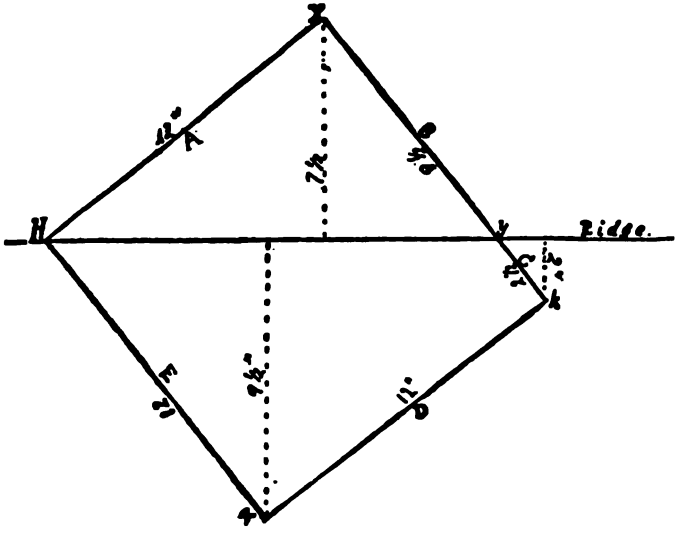

FIG. 1

on the ridge of a roof, as shown in Fig. 1. The roof is half pitch, or rises 12 inches to the foot. Required, the cuts for each side. The corner X is 7½ inches from the ridge; therefore it is 7½ inches lower than H. The cut for side A

is therefore 7½ to 12. X is also 7½ inches lower than Y. The cut for B is 7½ to 9½. The cuts for the other side are found in the same way.

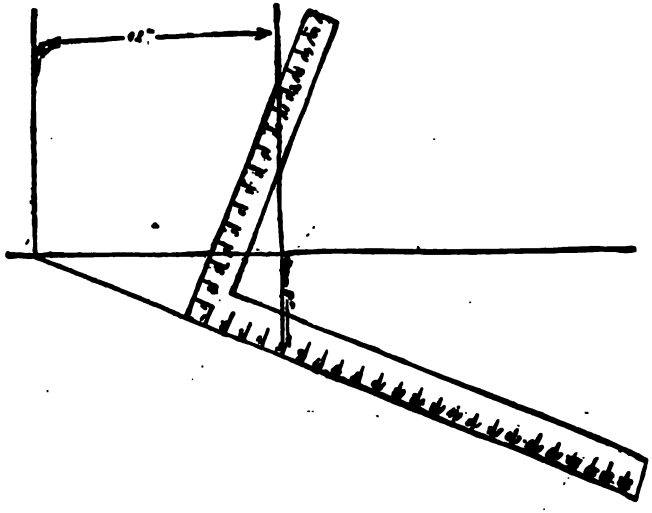

FIG. 2

For proof see Fig. 2. The side of the box being 12 inches, therefore, when set on the roof with one corner touching the ridge, or in any other position, it will reach 12 inches horizontally over the roof. And with a run of 12 inches you have a rise, or rather a fall in this instance, corresponding to the pitch of your roof. With the run on one side of your square and the rise or fall on the other, you will get the correct cut every time.

Two other problems are given here which I am sure will prove interesting:

To determine by a steel square the result of any number, for example, 6, multiplied by the sin 45°. Take 6 on both blade and tongue, and mark the line $ac=bc=6$. Then cd drawn to the middle of $ab=6\times\sin 45°$. Sin $75°=0.70711$. Fig. 3.

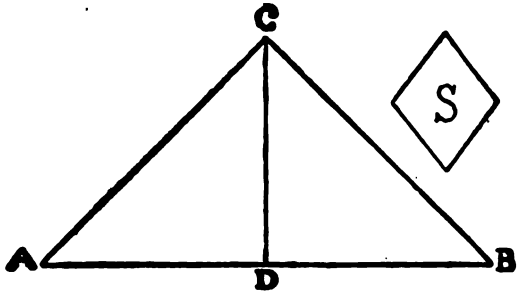

FIG. 3

Problem.—Referring to any rectangular framework which slopes alike on all four sides. *Given*—The rise and seat of the corner posts. *Required*—The cuts for the ends of the corner posts, the blade of the bevel to be applied to the two faces adjoining to the ridge line.

By the Steel Square.—On the blade take the rise. On the tongue take the seat then sin 45°. Mark along the tongue. The angle made by the tongue and the line is the proper bevel.

Problem.—Given—The run and rise of a com-

mon roof. We wish to place upon it a perpendicular square pipe to stand upon the roof diamond-shape, thus: *Required*—The cuts for the bottom end of the pipe; the blade of the bevel to be applied to the two faces adjoining the lowermost vertical edge.

By the Steel Square.—On the blade take the run of the roof. On the tongue take the rise × sin 45°. Mark along the tongue. The angle made by the tongue and the line is the proper bevel.

If the bevel is applied to mark the end of the higher half of the pipe, we have only to reverse the direction of the stock of the bevel so as to make an obtuse angle.

These two problems are very much alike. Their demonstration is a good study in solid geometry.

Suppose we wish to cut an opening in a roof for a round pipe or a tile, so that the pipe or tile will stand vertical through the opening. The exact form of the opening may be obtained by the following method, which is taken from "Carpentry and Building" of New York: set the pipe or tile to be used on the roof at the point where the hole is to be cut, as shown at Fig. 4; plumb

it with a level or plumb and place a square alongside of it as is shown in the sketch. Keep-

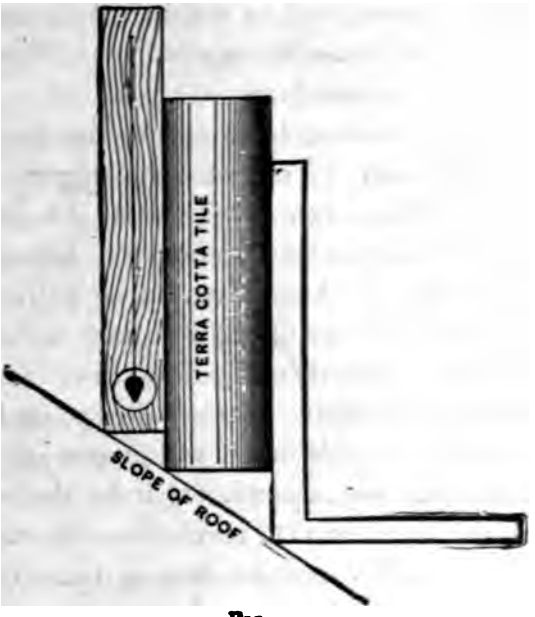

FIG. 4

ing the blade of the square in contact with the pipe, move it around the circumference of the pipe, touching the roof at points about one inch apart and making a mark on the roof at each point of contact. When the entire circumference of the pipe has been traveled, join the points marked on the roof, and the figure outlined will be a perfect ellipse and of exactly the size required. Nothing remains but to cut the

hole, and if this is done correctly the pipe will be found to fit exactly. This method is simple and perfectly accurate, and as it requires no calculation, it can be done by any workman who can handle the tools and pipe.

Often men working in wood-working factories find it necessary to increase or decrease the speed of a shaft a few revolutions. To get just the size of pulley necessary for this increase or reduction of speed requires close calculation when figures are used, but a square will do it off-hand and correctly every time. For instance, it has been ascertained that a pulley 20 inches in diameter on a certain shaft will give a speed of 13 revolutions per second. If it be desired to reduce the speed to 11½ revolutions per second, the 20-inch pulley must be removed and one of different size substituted.

To solve this problem with a steel square, take 20 inches on the tongue and 13 inches on the blade. Place both of the marks on the edge of a straight board and draw a line parallel with the blade. Move the square parallel with this line until the tongue shows 11½ inches instead of 13. Notice the reading on the blade and edge of the board. This reading will be size of pulley required in place of the 20-inch concern,

necessary to give the desired speed of 11½ revolutions per second. The principles involved in the calculations here made have been amplified and put into a more convenient shape for every-day use in the slide rule.

In this perfected form some mechanics are familiar with the tool, but all do not recognize it in the slide rule. The principle upon which all slide rules work is that of the square and the piece of board above mentioned. There are several more problems of this kind that might be described with interest to the reader.

To find the number of cogs in a wheel, pitch of cogs and diameter of wheel given, set the bevel to the pitch on the tongue and 3.14 on the blade.

Given the diameter of a wheel to pitch line, and number of cogs, to find pitch of cogs. A wheel 70 inches diameter has 146 cogs; what is their pitch? 146 inches being too great to set on the square, we take proportional parts, setting the bevel to $\frac{1}{2}$ inches or 8¾ inches on tongue and $\frac{1}{4}\frac{1}{8}$ inches or 18¼ inches on blades. Tighten the screw of fence, and move the bevel to 3.14 on blade, and the number given on the tongue multiplied by 8 will be the required pitch.

If we wish to divide a circle into a given num-

ber of parts, we proceed as follows: Multiply the radius by the corresponding number in column A, as per table, and the product is the chord to lay off on the circumference.

Given the side of a polygon, to find the radius of the circumscribing circle. This problem has previously been tabulated, but by multiplying the given side by the number corresponding to the polygon in column B, in most cases we obtain the answer more expeditiously.

No. of sides or parts		A	B
3 . . .	Triangle	1.732	.5773
4 . . .	Square	1.414	.7071
5 . . .	Pentagon	1.175	.8006
6 . . .	Hexagon	radius	side
7 . . .	Heptagon	.8677	1.152
8 . . .	Octagon	.7653	1.3065
9 . . .	Nonagon	.6840	1.4619
10 . . .	Decagon	.6180	1.6180
11 . . .	Undecagon	.5634	1.7747
12 . . .	Dodecagon	.5176	1.9318

Given the diameter of a circle, to find the side of a square of equal area.—Set a bevel to 9¾ on the tongue and 11 inches on the blade. Then move the bevel to the diameter of the circle on the blade and the tongue gives the answer. When the circumference is given instead of the diam-

eter, set the bevel to 5½ inches on tongue and 19½ inches on the blade.

To find the number of square yards in a given area we must proceed as follows: These problems require a bevel of 9 on tongue, and the length or width of the surface to be measured on the blade. The bevel is then moved to the remaining dimension of the area on the tongue, and the number on the blade indicates the square yards contained.

If the diameter of a circle is given, we can determine the circumference as follows: Set a bevel to 7 on tongue and 22 on blade; the answer will be found on the latter. In every case when a reverse problem is presented the bevel will solve it unchanged; we merely look for the answer on the other blade of the square. For instance, if, after solving the above, we are required to determine the diameter from the circumference, we still use the same bevel.

SOME DIFFICULT PROBLEMS AND THEIR SOLUTION

I am indebted to Mr. Fred Lascy of San Francisco, Cal., for some of the following interesting problems and their solutions. They make excellent practice for the young student who has made up his mind to learn all possi-

ble concerning the square and what may be done with it.

The workman is often confronted with problems in oblique framing that are difficult to solve unless he possesses knowledge of a high order of solid geometry. See how Mr. Lascy handles the square first in splayed work, then in oblique bevels. To construct on a base of any number of salient corners, a solid in which every two adjoining faces slope together toward the horizon forming a hip, and the same rise, of any lengths. To determine by the steel square on a line all the angles that can be required for such constructions, first draw to a proper scale the run AB, Fig. 5, the rise BD, and the slope AD. This triangle is supposed to stand perpendicular to the plane of the paper. Construct the angle ABC=B=any angle whatever. If all the corners of the base are alike in degrees, B=180°

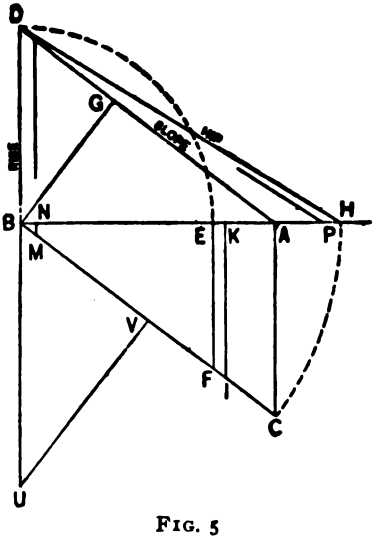

FIG. 5

divided by the number of corners. If the corners are unlike in degrees consider each corner by itself and make B=90°, minus half the degree, of this corner. Draw AC and BC, which is always the seat line of the hip. ABC is always half the corner of the base. All lines drawn from the run to the seat line must be at right angles to the run.

By the steel square. Place the slope on the blade. Place AC (run tan B) on the tongue. Mark along the blade for the face cut against the hip line of boards which have the direction of jack rafters. Mark along the tongue for the face cut against the hip line of horizontal boards; for the top cut of purlins; for the top cut of a miter box to miter the horizontal boards.

By the steel square. Place the slope on the blade. Place EF (rise tan B) on the tongue. Mark along the tongue for the miter cut across the square edge of horizontal boards; for the down cut of a purlin; for the down cut of a miter-box to miter the horizontal boards, lying flat in the box. If the boards be not mitered, we require the butt cut across the square edge of boards. For this draw BG, at right angles to the slope; make BK=AG, and draw KI=run cosine tan B.

By the steel square. Place the rise on the blade. Place KI on the tongue, and mark along the tongue for the butt cut across the square edge. Make BH=seat, then HD=hip line with its top and bottom bevels. For the diedral miter at right angles to the hip line, which is half the angle between any two adjoining sloping faces.

By the steel square. Place the hip line on the blade. Place EF (rise tan B) on the tongue, and mark along the tongue for the diedral miter, To back a hip rafter by a gauge mark, make B*n*=half the thickness of the hip, and draw *nm* to the seat; from the toe of the hip rafter make H*p*=*nm*, and from *p* draw the gauge mark parallel to the hip. For a four-sided hipped roof, we may need the side cut across the top square edge of the hip rafter against the ridge. For this make B*v*=half the seat, and draw *vu* at right angles to the seat, to meet B*u* at right angles to the run.

By the steel square. Place QUV (seat cotan B) on the tongue; place the hip line on the blade and mark along the blade for the side cut, shortening the hip according to the half-thickness of the ridge, thus: If B*n*=half-thickness of the ridge, draw a distance B*m* parallel to the rise; where this line cuts the hip shows the shorten-

ing. For a square corner, B=45° and R=co-tan B=1. In this case tangents of B may be drawn or not.

Again, let the raking molding of a pediment= AD, which is to miter against as horizontal molding that forms with the run of the pediment any angles whatever. B=90° minus half of this angle. The raking molding must be placed in the miter-box with that part of the molding which is vertical when in position against the side of the box.

Lay the steel square on top of the box. Place AG (run cosine) on the blade; place AC (run tan B) on the tongue, and mark along the tongue for the top cut of the miter-box. Again, place the run on the blade; place the rise on the tongue and mark along the tongue for the down cut of the miter box.

The miter of the horizontal molding equals one-half the corner on the ground plan. If the diagram ADB equals half the gable end of a rectangular building, to miter the raking planceer against the horizontal planceer, which slopes as the roof and runs along the eaves at right angles to the run of the gable, both planceers being in the same plane.

By the steel square. Place the slope AD on

the blade; place the run AB on the tongue; mark along the blade for the raking miter; mark along the tongue for the horizontal miter. The horizontal planceer requires the wider board.

In laying off angles for splayed work, lines as long as possible and as few as possible are the essentials of accuracy and comprehension of the subject.

Another problem with its solutions follows: Given a hopper or hipped roof which stands on a base whose corners have any angle whatever, and whose sloping sides have the same run and the same rise of any length. Required the dihedral angle between any two adjoining sloping sides without using the hip line; or, what is the same thing, to find the backing of the hip rafter without using the hip line. First lay off AB=run, Fig. 6, BD= rise, A D = slope line. Draw AC at right angles to the run, and lay off angle ABC=90°, minus half the angle of the corner of the base. Angle 6=half angle of corner of

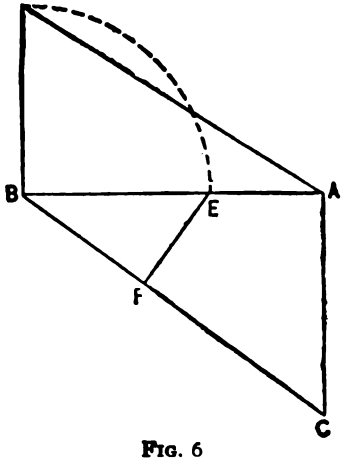

FIG. 6

base. Make BE=rise, and draw EF at right angles to BC, the seat of the hip line. On the edge of a board lay off GF, Fig. 7,=slope AD. By the steel square on the line GF, place EF on

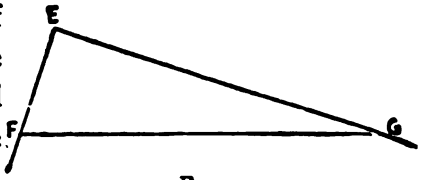

FIG. 7

the tongue and apply the tongue as shown on the diagram, moving the blade until the blade cuts the point G. Mark along the tongue. EFG= one-half the required diedral angle=diedral miter. By calculation: Cos diedral miter=rise cos half-corner angle C. The demonstration may be studied in any book on solid trigonometry which treats on the right triangular pyramid. It is too long to be given here. Without using the steel square, draw a semicircle on FG, and taking FE in the compasses, mark the chord line EF. This gives the diedral miter EFG to back the hip rafter.

The following problems in oblique bevels will prove both useful and instructive as well as interesting to the studious young workman: Given the run AC, the rise CB, Fig. 8, and the slope length BA of a stick of rectangular timber, which butts obliquely at the upper end against a vertical plane of indefinite length, and whose

seat line=CE. Angle between this seat and the given run=W, which may be any angle whatever. Required the side bevel on the top face of the stick at the point B to fit this end of the stick against the vertical plane. First draw AE at right angles to the run, make AD=slope and draw DE. The required side bevel =EDA. Demonstration: Let the triangle EDA revolve on AE as on a hinge; when the vertex D reaches the required height of the rise, the triangle EDA will stand directly over the triangle ECA, the line ED will coincide with the vertical plane, the line DA will coincide with the top center line of the stick. By calculation, tan side bevel $= \frac{\text{run tan W}}{\text{slope}}$ when $W = 45°$, tan W = unity. By the steel square on a line: Place AE (run tan W) on the blade, place the slope line on the tongue, mark along the tongue for the side bevel.

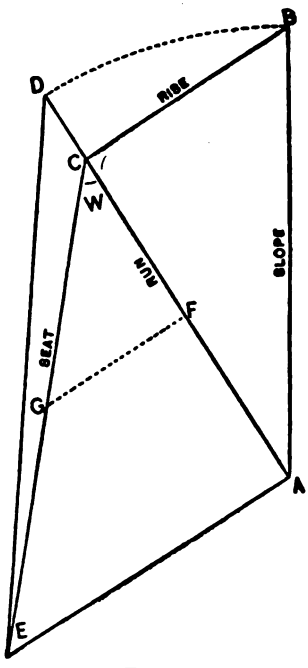

FIG. 8

When W is an obtuse angle it will be more convenient to obtain the length of AE in the following manner: From *f*, the center point of the run, draw *fg* at right angles to the run, then AD=twice *fg*. If the stick should at its lower end butt obliquely against a vertical plane, the side bevel is obtained in precisely the same way as given. By this method we may obtain the side bevel at the lower end of certain jack rafters, making planers and rafting moldings. The other bevels at the top and bottom of the stick do not require any remarks.

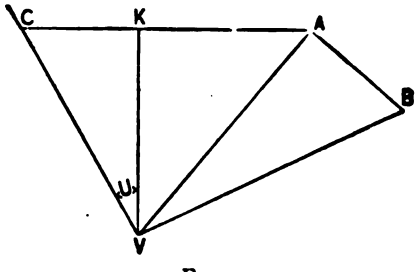

FIG. 9

Again, given the run KV, Fig. 9, the rise KA and the slope AV of a stick of rectangular timber which at its lowered end V butts obliquely against a vertical plane whose ground line is in the direction of VC. The corner KVC=*u* may be of any size, and is supposed to stand perpendicular to the plane of the paper. Required for the lower end of the stick the miter cut across the top face; also the down cut, so that this end of the stick may fit against the vertical plane

whose ground line is VC. First, from the point K, and at right angles to the run, draw KC to intersect the ground line of the vertical plane. From the point A, and at right angles to the slope, draw AB=KC; also draw BB; then AVB is the miter cut across the top face. Demonstration: The triangle VKA being perpendicular to the plane of the paper, let the triangle VAB revolve on VA as on the hinge, until the line AB comes into the horizontal position over KC; then AVB is the required sloping triangle of which KVC is the plan. By the steel square on a line: Place KC on the blade and the slope VA on the tongue. Mark along the tongue for the top face miter. The end down cut may be marked by a bevel set to the angle KAV. The stock of the bevel is applied along the bottom face of the stick with the blade of the bevel pointing upward along the side face. The most common applications are the rafters which butt obliquely against valleys, hips and ridges. If the line VA represents a raking planceer, which at the lower end of a gable miters around a square corner and against a horizontal planceer that slopes in accord with VA, then the angle *u* is always 45°, and CK and AB will each equal the run VK. The miter for the end of the hori-

ntal planceer will be the angle ABV. The ırizontal planceer is supposed to have its inside lge beveled to fit against a vertical plane; a quare mark down the beveled edge is the down ut through the thickness of the mitered end of he wider horizontal planceer. VA and VK show the relation between the width of the two planceers. If VA is a raking molding, mitering at point V around a square corner and against a horizontal molding. The lower end of the raking molding, mitering at point V around a square corner and against a horizontal molding. The lower end of the raking molding should be cut in a miter-box, with that part of the molding which is nailed against tne gable placed against the side box. The foregoing are the proper cuts for the miter-box. The line KC, etc., may be drawn anywhere along the line KV.

Here is an excellent graphical method of finding the areas of different figures. It is taken from "The American Machinist," and is worthy, I think, of a place in this work, because of its compactness and simplicity.

When the area and diameter of any circle is known, by this method the area due to any other diameter, or a diameter due to any other area, may be determined. Suppose we take the diam-

eter 2 with the area 3.1416 as the known quantity from which to calculate all others. Any other diameter and area may be chosen, but this one is the easiest to remember. Draw the indefinite straight line AB, Fig. 10, and, with a diameter equal to 3.1416, draw the semi-circumference ADC. With a radius equal to 2, and with A as a center, cut the semi-circumference ADC in D. Through D erect the perpendicular HE, then will the distance AE be a constant for every diameter and area. Let it be required to find by this diagram a diameter that has an area equal to 5. Lay off AF=5 and draw the semi-circumference AGF, then will the distance AG be the required diameter. If the diameter is given and the area required, take A as a center, and, with the given diameter as a radius, cut the line HE in G. Bisect the line AG at right angles with the line, cutting AB in K, then will K be the center of a circle passing through A and G, and its diameter, AF, will be the required area.

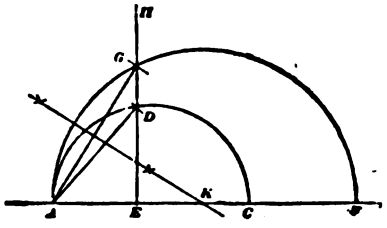

FIG. 10

This diagram is susceptible of a great variety of applications. The diameters on the line

AB may be areas, capacities, weights, tensile strengths, or, in fact, anything that is made up of area and a constant quality. The distances from A to the line HE are always diameters, sides of a square or some constant component of area. The distance AE is different for each kind of proposition, but is constant for every proposition of the same kind. If we say that a bar of 1-inch round iron has a safe tensile strength of 7,000 lbs., then we lay off AF=7, draw the arc on this diameter, and lay off AG=1. The position of G gives the location of the line HE, from which the tensile strength for any diameter may be found. A diameter AD will have a tensile strength AC.

The advantage of this diameter lies in the fact that it is impossible to remember all areas, weights, strengths, etc., while it is comparatively easy to remember one out of each table. With this one known, it matters not whether the tables are at hand or not, as it is comparatively easy to find any other without calculation or liability of error.

It is a well-known geometrical fact that the angle within a semi-circumference is a right angle. Pattern makers may take advantage of this in making of core-boxes, in the manner

shown in Fig. 11. If the core-box has been cut out accurately, then the square will touch at three places—the two edges and a point in the curve. If it touches at only two places, one being on the curve, then it is not cut out deep enough; if it touches only at the two edges, then it is cut too deep by the amount of clearance between the corner and the curve. By giving the square an oscillation, to make the corner sweep the entire surface of the curve, the accuracy of the curve at that point may be ascertained, and by trying at several points the truth of the whole box may be determined. The square may thus be made to take the place of a templet in making of core-boxes, with the advantage that the square will fit any size, while a templet only fits one. There is an opportunity here for some one to get up a core-box plane that will produce any semi-circumference accurately and quickly. The only care that would have to be exercised by the workman would be the placing of two parallel metal strips as shown

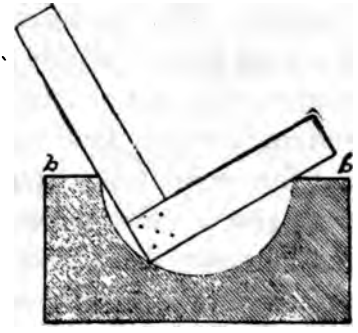

FIG. 11

at *a* and *b*. These strips are, of course, not necessary when simply using the square to test the accuracy of the work, but would be necessary in the use of a core-box plane made on this principle.

If we wish to find the diagonal of a square or parallelogram, all we have to do is to set the blade of a bevel to 8¾ inches on the tongue and 12⅜ inches on the blade. Then screw the bevel fast; and supposing the side of the square in question is 11 inches, move blade to the 11-inch mark on the tongue, keeping blade against the square, when blade will touch 15⅛ inches on the blade, which is the required diagonal. There is no special reason for using 8¾ and 12⅜; other numbers may be employed provided the proportion of 70 to 90 exists between them. In the problem just solved, as in all that follow, the bevel being once set to solve a particular question will solve all the others of the same kind, till the bevel is altered.

To find the circumference of an ellipse or oval, we proceed as follows: Set 5⅝ inches on the tongue and 8¾ inches on the blade. Then set the bevel to the sum of the longest and shortest diameters of the ellipse on tongue, and the blade gives the answer.

If it is desired to find the side of the greatest square which may be inscribed within a circle we can accomplish it with the aid of the square as follows: The diameter of a circle being given, set the bevel to 8½ inches on the tongue and 12 inches on the blade. The answer will be found on the tongue.

To inscribe three small circles within a large circle of given diameter, set to 6½ inches on tongue and 14 inches on blade. Move the bevel to the given diameter on the blade and the required diameter appears on the tongue.

Four equal circles require a bevel of 2.91 and 14.

To inscribe polygons within circles.—In the following table, set the bevel to the pair of numbers under the polygon to be inscribed:

No. of sides	3	4	5	6	7	8	9	10	11	12
Radius	56	70	74	side equal to	60	98	22	89	80	85
Side . .	97	99	87	radius	52	75	15	55	45	44

If we require the radius of a circle which will circumscribe an octagon 8 inches on a side, we refer to column 8, take 98 parts on the blade and 75 on tongue, and tighten the bevel. As the side of a hexagon equals the radius of its circle, the side of an octagon must be less than the radius; hence we shift to 8 inches that end of the bevel

blade which gives the lesser number, in this case on the tongue of the square, as the 75 parts to which the bevel was set are less than the 98. The required radius is then indicated on the blade.

The following is another table, to be used for the same calculations:

Names	No. of sides	Gauge points
Triangle	3	10.44
Square	4	8.49
Pentagon	5	7.06
Hexagon	6	6.00
Heptagon	7	5.24
Octagon	8	4.59
Nonagon	9	4.05
Decagon	10	3.71
Undecagon	11	3.38
Dodecagon	12	3.11

In a circle 12 inches in diameter, the largest pentagon which may be inscribed is 5.24 inches on a side. Hence for pentagons the bevel is set at 12 inches and 5.24 inches. The number opposite each polygon gives its side when inscribed in a 12-inch circle.

The first table is usually most convenient.

When the side of a polygon is given, to find its apothem or perpendicular.—Set the bevel to the pairs of numbers in the table below. Thus, for a

heptagon, set 23 on tongue and 25 on blade, and the answer will appear on the latter.

Sides .	3	4	5	6	7	8	9	10	11	12
Apothem	9	1	20	13	25	40	40	20	29	28
Sides .	31	2	29	15	23	33	29	13	17	15

The board measure.—A foot in board measure is 1 inch thick and 1 foot square. Set the bevel to 12 inches on the blade and the length of board in feet on the tongue. Then move the bevel to the width of board in inches, on the blade, and the area in square feet appears on the tongue. Whenever the 12 inches is set, whether on tongue or blade, there also must be set the width of board in inches.

To lay off degrees with the steel square, consult a table of tangents, and from this table take the tangent of the angle required, using the first three figures from the left and calling them so many 64ths on an inch. Reduce them to inches, and then, with this quantity on one side of the square and 15⅝ inches on the other side, we will have the figures for laying off the angle. Tables of natural tangents are usually calculated to the radius unit, and are therefore decimal fractions. This method is simply to multiply each by 1,000, thereby obtaining whole numbers. For exam-

ple, let it be required to lay off an angle of 10°, the natural tangent of which is 0.176327. Multiplying this by 1.000 makes 176.327. Discarding the decimal we have 176, and calling the figures 64ths of an inch, we have $\frac{176}{64}$, or 2¾ inches. The radius 1 treated in like manner makes $\frac{1000}{64}$, or 15⅝ inches. Now, taking 2¾ inches on the tongue and 15⅝ inches on the blade of the square, the blade gives the angle of 10°, and consequently the tongue gives 90° less 10°, or 80°. There are other methods of laying off degrees with the square, several of which I have described and will describe hereafter.

PROPORTIONAL REDUCTION OF MOLDINGS OR OTHER WORK

There are many methods of doing this work by lines, ordinates, and the pantagraph, but I do not know of many by the steel square. The following, which may be new to many readers, has been in use for a long time: First draw the molding bracket or other work, as shown at Fig. 12, in a square as at A, B, E, F. Square out from A and F lines meeting at B. Draw BE, and from E measure off the required projection of the reduced bracket, thus obtaining the point D. Square down from D to the line BE, thus loca-

ting the point C. Then the line ED will be the width of the reduced bracket and DC its height.

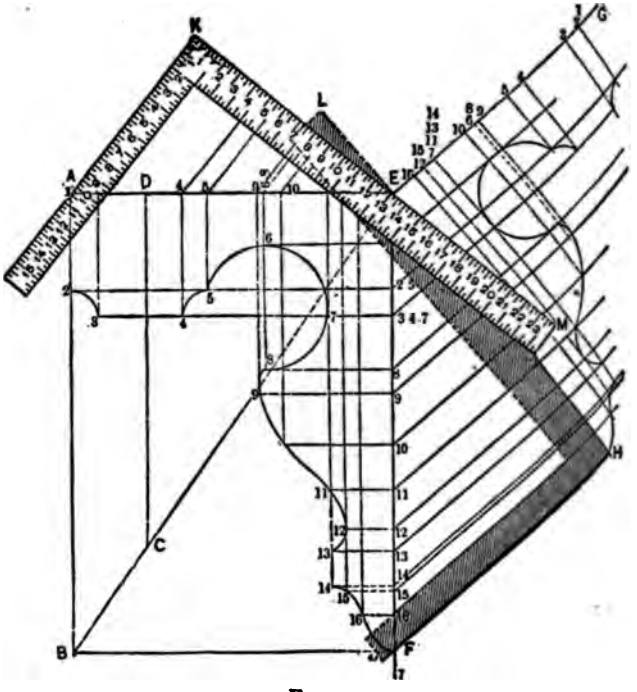

FIG. 12

Now, at convenient points, their location and number being determined by the nature of the profile, as 2, 3, 4, 5, etc., square lines to the back edge, and also to the upper end of the brackets, all as shown in the sketch. Take the width ED of the reduced bracket on the blade of the square, and placing it, as shown in the engra-

ving, against the corner E, carrying the tongue of square up until its edge strikes the outer corner A of the original bracket, draw a line along the blade, all as indicated by KE. Square down from points in this line to the points in the upper line of bracket, 1, 3, 4, 5, etc., already obtained. Take the length of the line DC on the square, which is the length of the bracket after reduction, and place it, as shown by the shaded square in the sketch, at E. Carry the square up until the blade strikes the corner at F. Mark along the blade of the square, thus producing the line EH, which is the back of the diminished bracket. From this line square out the line EG indefinitely; also square out the lines 16, 15, 14, 13, etc., from the points in the back edge of the original bracket, extending them indefinitely across the space the reduced bracket is to occupy. Take a straight-edge and place it against the line KE and mark the points that have already been obtained in it. Then transfer these distances on to the line EG. If preferred, this may be done by the compasses, setting one leg at E and describing arcs from the several points in KE, striking the line EG. From the points thus located in EG lines are then to be carried at right angles to it, being produced until they meet

the lines drawn from corresponding numbers on the inner edge of the original bracket. Then a line traced through these intersections will produce the profile of the bracket diminished. The number of fixed points in the profile of the original bracket necessary to be used will vary in different cases. Where the lines are long and regular less will be required than where they are short and irregular. To increase the size of a given bracket the process here described is to be reversed. The same general rule may be also applied in drawing the profile of raking moldings. I think it will be seen that I have not here laid down an arbitrary rule. The principle on which it is founded is in laying down a line the length of the required bracket, and dividing that line in the same proportion as the original bracket.

It is required to get the length of a hoop for a wooden tank, by the steel square.—To accomplish this, proceed as follows: First produce a circle to any desired scale, say 1 inch to the foot, and this on 24 feet would be 24 inches. Then place the heel exactly at the center, as indicated in Fig. 13, and scribe closely to the square, cutting the circumference of the circle, as indicated by BC. Then draw the chord intersecting the

points B,C already referred to. The next step is to divide the segment equally, which is done by the line DE. Now three times the diameter plus the distance DE will give the required measurement or circumference.

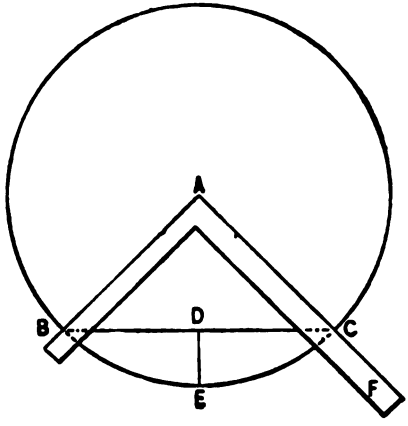

FIG. 13

To perform this by figures alone, take the diameter of the tank and multiply it by 3.1416. If the diameter of the tank is 24 feet, for example, the equation is as follows: $24 \times 3.1416 = 75.3984$; or multiply the diameter by 22 and divide by 7. Thus $24 \times 22 \div 7 = 75\frac{3}{7}$.

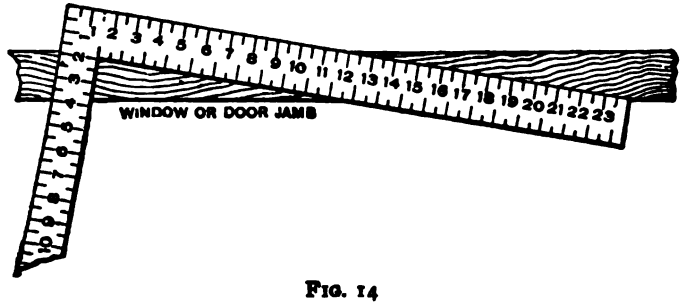

FIG. 14

The proper angle for ordinary door and win-

dow sills is about 1 inch drop to the foot. A method of finding this inclination quickly is shown in Fig. 14. The square may be laid on the edge of the bench, or on the edge of a board, and the bevel set to suit in short order.

SOME MISCELLANEOUS PROBLEMS

These problems are gathered chiefly from the "Scientific American" Supplement, and were originally contributed by Mr. O'Connell. Some of them are more curious than useful, but all are interesting.

The arms of a straight horizontal lever are 8 and 12. A weight of 9 lbs. is suspended from the shorter arm; what weight will balance it on the longer arm? Set to 12 on blade and 8 on arms. Move the bend to 9 on blade, and 6 is the answer on tongue.

What power is required to support a weight of 4 lbs. on an incline of 5 in 30? Set 5 on tongue and 30 on blade. Move the bevel to 4 (lbs.) on blade, and ⅔ (lb.) is obtained on tongue.

A body is weighed in a false balance and in one scale appears to be 9 oz. and in the other 12 oz. What is its true weight? Find a mean proportional between these numbers, that is, the square root of their product. $9 \times 12 = 108$.

$\sqrt{108}$=10.39, Ans. The same example is solved by the square by taking 10½, half the sum of 9 and 12, and 1½, which is the difference between 10½ and 9, or 12. The 10½ is now the hypothenuse of an imaginary right-angled triangle, and the 1½ one side. It has already been explained how to find the other side, or the answer.

A spout is 20 .nches square; what is the diameter of a cylindrical one with the same area of cross-section? Set the bevel to 31 on tongue and 35 on blade. Move to 20 on tongue and we obtain 22, the answer on blade.

The length and angles of a brace of irregular run, or any run, may be found readily by applying the following rule, using the square as you would a drawing made to scale: Take, for example, the case of a brace of which the run is 49 inches and the height 37 inches. Measuring across the space for the length of the brace with a square will not do; accordingly, then reduce the two lengths by four, which gives 12¼ and 9½ respectively. By taking these points on the two arms of the square and measuring across, the required length will be obtained. To do this take a piece of board, joint one edge and run a gauge mark from the edge the desired width.

Then, placing the square so that the figures fall on the gauge mark, apply it four times, scribing along the blade and tongue respectively for the two ends. This gives the net length of the brace and the proper cuts for the joints. This may not be the best rule which can be employed for the purpose, but it is short and simple. Any ordinary carpenter can work it, and it is undoubtedly correct.

At this point I show a few quick rules to give a square stick an octagonal shape. The rules given on the side of the square as shown in my description of squares in the first volume, while being perfectly correct so far as they go, do not work so well where fractions of an inch are involved, so the following methods of finding the points for the gauge lines are shown at Fig. 15, which shows the square as laid obliquely across the face of the stick so that just 6 inches will be on the stick. At 1¾ inches from each corner draw gauge lines, which will be the correct corners for the octagon. If the timber is over six inches square lay twelve inches of the square upon the

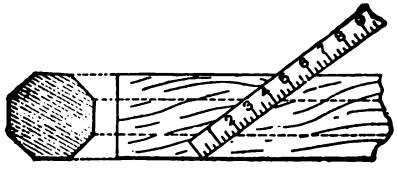

FIG. 15

:e and gauge at 3½ inches from the corner. If er 12 inches wide, lay over the whole 24 inches the square and prick off 7 inches from each d, and these points will be the gauge points. deed, it is best to use the whole length of the

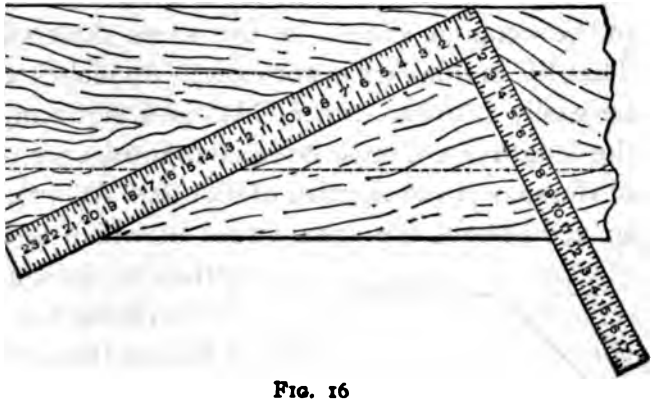

FIG. 16

uare in laying off work of this kind, and prick- g off 7 inches from each end of the square, no atter what may be the width of the timber. g. 16 shows this method quite earl y. The dotted lines rep- sent the gauge marks. Fig. shows a section through e corner of a timber; B and represent the gauge marks an adjacent face of the tim- r, and are each 7 inches removed from the

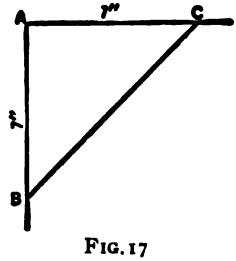

FIG. 17

corner A. The timber, of course, is to be dressed until the line BC becomes a surface. Now, if the rule were accurate, the diagonal BC in Fig. 17 should measure exactly 10 inches, because the adjacent faces, by the rule, would be laid off by measurement to that dimension, and all the faces of the octagon should be the same dimension. That BC in this case is not exactly 10 inches may be easily proven. Since CAB is a right angle, the length of CB must be equal to the square root of the sum of the squares of BA and AC ($7\times7=49$, $49+49=98$), the square root of which is less than 10, the square of 10 being 100. It follows that a stick of timber reduced to octagon shape by this rule will have four of its sides 10 inches in width and four of its sides a fraction less than 10 inches, equal to the square root of 98. Fig. 18 shows the same thing in a little different shape, by representing a partial section through a timber 24 inches square. The gauge marks C and D are each 7 inches from the corners A and B; the side CD is 10 inches, but the sides CB and

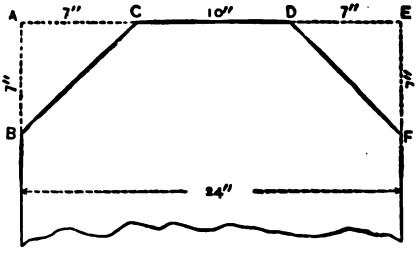

FIG. 18

DF are less than 10 inches. As this rule, like some others in common use, is supposed to be mathematically accurate, I think the diagrams introduced will be of interest to readers.

SOME GOOD THINGS

A whole bunch of good things, some original, some gathered from the four quarters of the earth, are shown in the two illustrations following, which have been handed me by Mr. Stoddard, to include in my "Odd Things Done by the Steel Square." Some of these examples have already been given under various heads, but a repetition is excusable when placed before the reader in another light. These problems were published in "The Carpenter" some time ago, and were well spoken of by a large number of woodworkers.

After stating that he was much indebted to Hodgson for his knowledge of the steel square, Mr. Stoddard goes on to say to the workman "that, to advance rapidly he should be a faithful student and observing, and should notice how every new piece of work is done, and should purchase some good works on the subject in hand." Then he goes on to describe the various meth-

ods of roof framing as illustrated in the seven illustrations shown in Fig. 19, as follows:

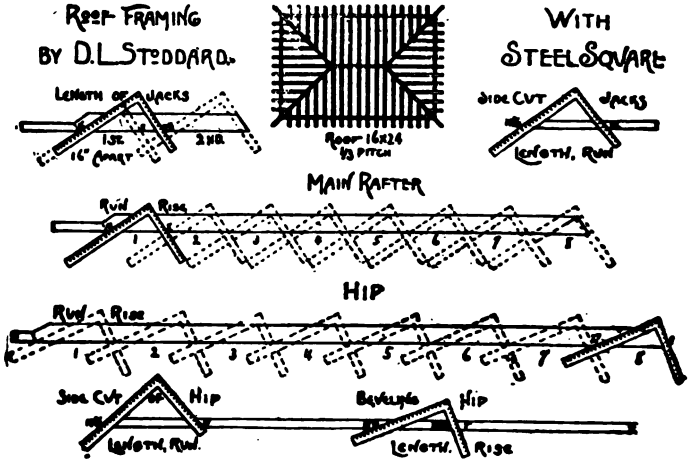

Fig. 19

ROOF FRAMING

In the cut I have illustrated a ⅓ pitch hip roof, 16×24 feet, rafters 16 inches apart.

MAIN RAFTER

One-third pitch rises 8 inches to the foot, and as 8 feet is half the width of the building, the run must be 8 feet. Therefore put the square on 12 and 8 and eight times gives the length and bevels (as illustrated). Notice how it is squared up at heel, and amount allowed for ridge.

CENTER HIP RAFTER

As the diagonal of a foot is 17 inches, take 17 inches on blade in place of 12, and we have hip rafter (as illustrated).

Now these methods are not new or original, as they have probably been used for ages, yet it is surprising how few carpenters know them.

JACK RAFTERS

My method for jacks is an original idea to me, yet it may have been used before I was born.

I simply lay the square on the same as for common rafter. If you wish them 16 inches apart, move the square up to 16 inches; if 18 inches apart, move up to 18, etc. The side cut is the length and run. Cut on length. If you wish to bevel top of hip, take length and rise. Cut on rise.

OBSERVE ALL THE ILLUSTRATIONS

Now remember the same method applies to all pitches. Run the same; simply change the rise to whatever rise the roof is to the foot. This applies to cornice as well as rafters.

Do not be satisfied with this knowledge, but study the use of the square and go further, as there is no limit to what can be accomplished with it.

PRACTICAL USE OF SQUARE AND RULE

Study and fully understand the eight illustrations in this one little cut, and you will find, by thought and application, as the occasion requires, you have learned a great deal, as you will readily learn more.

If you have a board 7 inches wide and wish to divide it into four equal parts, turn the rule until

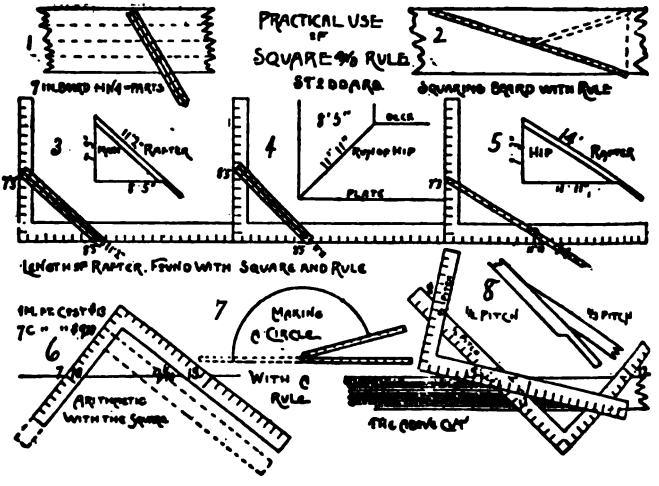

FIG. 20

it strikes eight inches, and mark at each 2 inches, as in No. 1, Fig. 20.

I use that almost daily not only in ripping up boards but in drawing, etc.

If you happen to wish to square a board and

do not have a square, take a rule and apply as shown in No. 2, Fig. 20.

IN LAYING OFF RAFTERS

Some may not like to place the square on once for every foot of run, as I illustrated in another cut. Also, if it is to go to a given height one may not wish to stop to figure the exact rise to the foot, figuring out the fraction, etc. Take a roof to be 7 feet 3 inches high and run 8 feet 5 inches. Put your rule on $7\frac{3}{12}$ and $8\frac{5}{12}$, and you will have $\frac{11}{12}$ or 11 feet 2 inches length of rafter, as seen at No. 3, Fig. 20.

If you wish to hip the same roof, as it is 8 feet 5 inches to the deck, the run of hip must be the diagonal of 8 feet 5 inches, which is 11 feet 11 inches, as illustration 4. The run being 11, 11, and the rise 7, 3, place the rule on them, and we have 14 feet, as shown in No. 3, Fig. 20. If you are buying lumber at $13 per M, and you wish to know what 7000 feet costs, place the square on 10 and 13, bring it down to 7 on the tongue, and we will find we have $9\frac{1}{12}$ on blade, or $9.10, which is the correct answer, as shown in No. 6, Fig. 20.

If you wish to strike a circle and have nothing but a rule, apply as shown at No. 7.

One noon a large crowd of workmen was asked by the foreman how to cut a third-pitch rafter so it would lay on half-pitch roof. It seemed to me to lay off half-pitch and then from that half-pitch line lay off ⅓ would cut it. I tried it, and we were all surprised to find it O.K., as shown at No. 8, Fig. 20. All of these problems, as formulated by Mr. Stoddard, are valuable in themselves because of their simplicity and because of their paving the way to many other things. Indeed, as I have often stated, there appears to be no limit to the use of the square; and I am sure there are hundreds of workmen scattered over the country that have found out things that can be done with this tool, of which we never hear, and I would like to impress on the minds of the readers of these volumes the fact that if they have any new "kink" they have worked out with the square, they will be doing a public good by sending a description of same to the publishers of this work, so that it may be published in future editions, and thus saved to the trade.

TO OBTAIN THE LENGTH OF A HOOP FOR A BARREL OR TANK BY THE STEEL SQUARE

There are a number of ways by which the length of a tank or barrel hoop may be obtained,

some of them being much easier than the one I am about to describe, as using a traveler, for instance, after the tub is standing, or stretching a tape-line around the tub, and other ways; but where these methods cannot be applied—which is very often—then the following method may be employed with profit: The diameter being known, the circumference may be obtained by the ordinary rule of multiplying the diameter by 3.1416, which will give the circumference nearly, then take a pair of dividers and strike a circle to a scale of say ⅜ or ½ inch to the foot; then

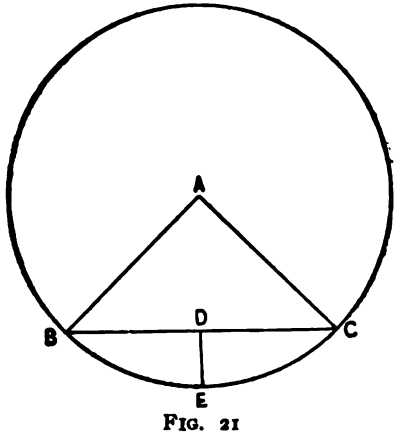

FIG. 21

place the outside corner of a steel square to the center of the circle, as at A, Fig. 21. Referring now to the sketch, scribe along the outside of the square from B to A, and from A to C, then draw

a line from B to C, intersecting at the points where the lines previously drawn cut the circumference of the circle. Now obtain the center on the line BC, as at D. Take the square and place it with one edge at the center of the circle, cutting the line BC at D, and draw the line DE. Multiply the diameter of the circle by 3 and add the distance from D to E. For example, suppose the tank is 24 feet in diameter; the circumference would be 75 feet 6 inches; thus $3 \times 24 = 72$ plus the distance from D to E, which is 3 feet 6 inches, making 75 feet 6 inches. The sketch so clearly shows the method that further explanation would appear to be unnecessary.

TO MEASURE INACCESSIBLE DISTANCES BY THE AID OF THE SQUARE

A number of writers on the steel square have written on this subject and have got the matter down fine; but the best of the articles I have met with are those of Lucius Gould of Newark, N. J., and A. W. Woods of Lincoln, Neb., the latter, in my opinion, being the better of the two, and it is from the latter that the following is largely taken, as it is placed before the readers in a simple unostentatious manner.

Every mechanic knows that a triangle whose

asure 6, 8 and 10 forms a true right
l is the method commonly used in squar-
dations. But how many ever stopped
what other figures on the square will
same result?

ferring to trigonometry we find only
ices, using 12 inches on the tongue as a
l measuring to the inches on the blade
not end in fractions of 1 inch on the
ause side. They are as follows: 12 to 5
, 12 to 9 equals 15, and 12 to 16 equals 20.
as we usually use a 10-foot pole to
ap a foundation, we find
f the above contain lengths
than our pole, so we must
ir proportions. The first
numbers not divisible
fractions, consequently we
on to the next. We find
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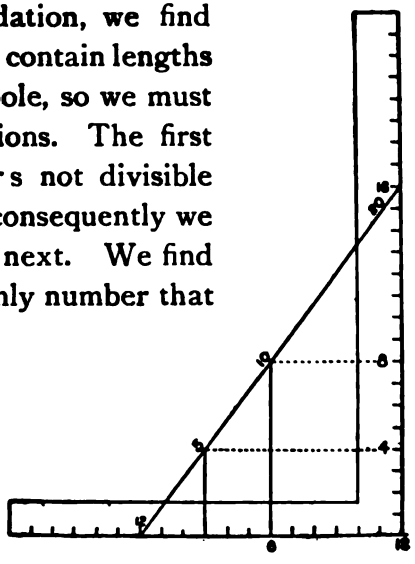


FIG. 22

Now let us examine 12, 16, and 20. They are even numbers, and are divisible by 2 and 4, Fig. 22. If we take one-half their dimensions, we have 6, 8, and 10.

These being convenient lengths and easily remembered, custom has settled on these figures.

There are other places that 6, 8, and 10 can be used to advantage.

Suppose for some reason we want to know the distance across a body of water. We cannot wade it, neither can we depend on a line stretched across, because when it is re-stretched on an accessible place of measurement we have no way of determining when it is drawn to the

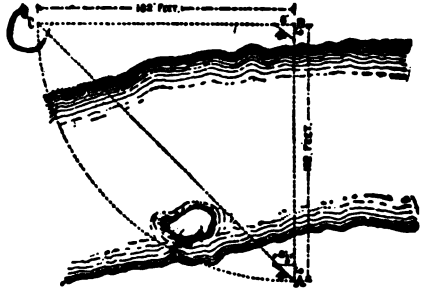


FIG. 23

same tension. Now, referring to Fig. 23, we want to find the distance from A to B. Lay off the angle of 6, 8, and 10, at both A and B, as shown.

Since the base and perpendicular of a right angled triangle are of equal lengths when the hypothenuse rests at 45° with the former, we measure off 6 feet on the 8-foot side as shown, and this will be the point of sight from A. With a man sighting from both A and B, a third sets the stake at C. Then BC must be the same length as AB. (The arc is shown here to prove the accuracy of the diagram.)

By measuring from A and B to the water's edge and subtracting the amount from BC will be given the width of the body of water.

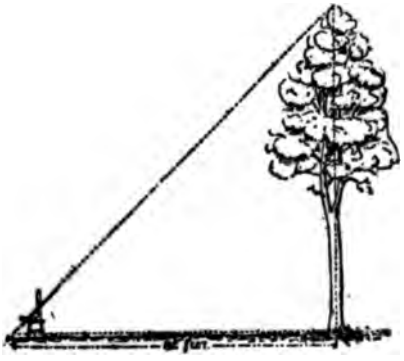


FIG. 24

Fig. 24 illustrates how a tree or inaccessible height can be measured on the same principle with the aid of the steel square. Take a straight-edge and fasten at any of the equal figures on

the tongue and blade. Level and set as shown, and the base will be equal to the perpendicular.

MAKING TRESTLES BY THE AID OF THE STEEL SQUARE

The usual batter given to trestles is 3 inches to the foot, but any figures may be taken, according to the amount of batter required.

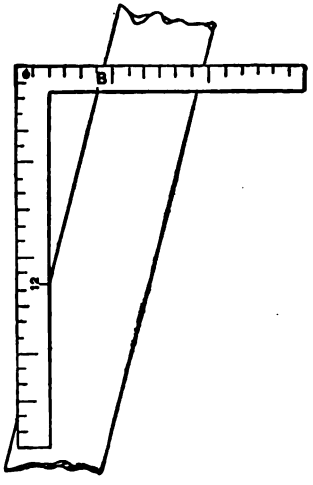


FIG. 25

The manner of using the square to obtain the proper angles and bevels is shown at Fig. 25, which shows how the vertical and horizontal cuts can be determined.

Fig. 26 shows the end of a framed trestle, with posts on the same inclination as shown at Fig. 25. It also shows braces, one framed in the angles and the other spiked on.

This problem may be applied to all tapering framework when the taper or lean is in one direction only. When the work is pyrami-

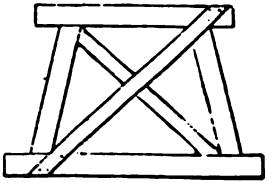


FIG. 26

dal, or leaning two ways at the corners, then a different mode of obtaining the bevels must be adopted. I will refer to this again.

SOMETHING MORE CONCERNING ROOF FRAMING

In cutting the timbers for a hip or valley roof, or for both, it will readily be seen that the principle involved in getting the lengths and bevels is the same as for getting the lengths and bevels for braces, for if you compare the top end of a brace with the ridge and valley rafter in a roof, it will soon be seen that they are the same.

Let us take a square stick, say a 4x4, it will form a half-pitch. If the brace is set at an angle of 45°, you get the bevel as shown at Fig. 27.

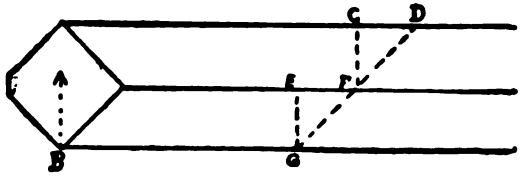


FIG. 27

Now take one-half of the diagonal width, as at AB, and measure this distance along the edge of the stick, as at CD. Square over to the other angle and join DF. Measure as before, making EF equal to CD. Square across timber again, and FG will be the cut.

For a simpler way, that will suit all braces and at any angle, take a piece of timber and mark as above. Suppose you have a 4x4 to be cut, say 6 feet from a post, and run up on the post 8 feet 6

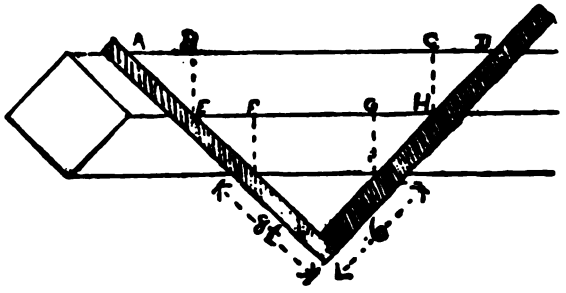


FIG. 28

inches. Lay he square on the lines laid down thus (see Fig. 28):

Transfer the distance AB in Fig. 28 to the side

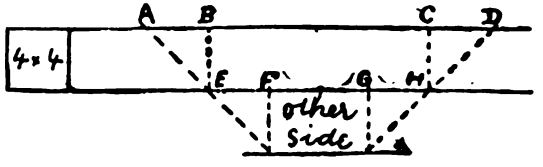


FIG. 29

of the timber in Fig. 29. Square over to the other edge, and join the angles as before; then cut.

Another way: Take your square and find the distance across from 8½ on one arm of the square to 6, Fig. 30, on the other same as for a

common rafter. This distance will mark the side, using the line formed by the arm of the square with the 6.

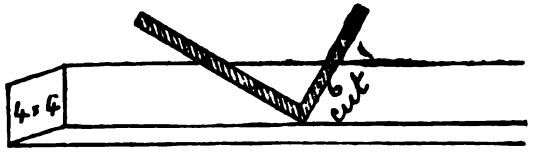


FIG. 30

Cross over on the other side and cut, as shown.

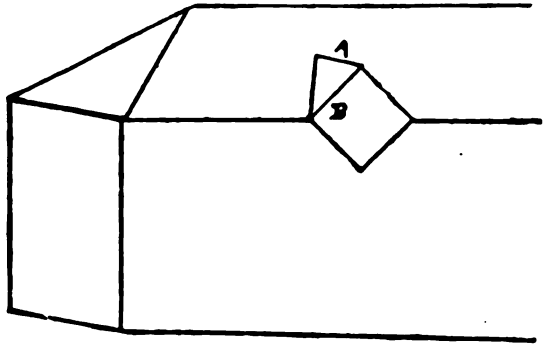


FIG. 31

AB, Fig. 31, represents the ridge or edge of the 4x4; line to the left of B the valley or side of the 4x4. It will be noticed that the ridge A is one-half the width of the width B.

Of course this proposition holds good, and practical experience has so proven it. Any distance may be used instead of those given, by applying the instructions as shown.

These instructions apply more particularly to roofs when the pitches are equal, but there are many cases where the pitches are not the same on each side of the roof, and to meet this inequality the following diagrams and explanations

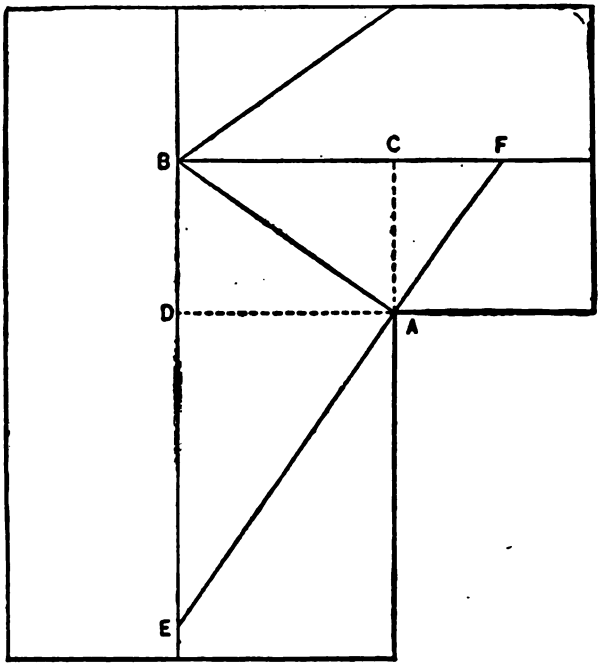


FIG. 32

are given: Let us examine Fig. 32, here we have the valley AB and the run of the common rafters AC and AD, of unequal lengths. To obtain the cuts for the top of the valley rafter draw AE and

AF at right angles to AB extending them to the ridge line. Now AE and the length of the rafter on the square gives the cut ABE, and AF with the rafter gives the cut FBA, marking on the side representing the rafter. The lengths of these auxiliary lines may be obtained by laying the square on the roof plan and noting their lengths by the scale of the drawing, or, better yet, by a little simple proportion, as exemplified in Fig. 33, of the sketches—AC : AD :: AB : AE.

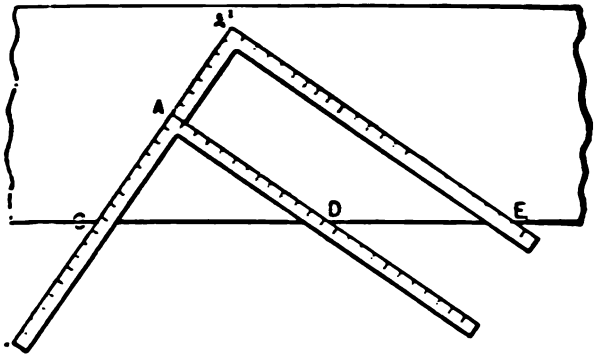


FIG. 33

That is, take the runs of the common rafters, as AC and AD, on the square, place them on the edge of a board and mark along AC; then slide the square on the line AC until A'C equals CD; then A'E equals AE of Fig. 32. For the valley jacks use the length of rafter over AD with run

AC for the angle DAB and the reverse of the opposite side. It is seldom if ever that a drawing is necessary.

On the subject of the steel square as used in laying out roofs, I cull the following from an English source, which, while containing nothing new to those who have made a study of the steel square and its applications, yet is interesting as it offers another side light, as it were, to the subject, and contains some things that may prove instructive.

Regarding the lengths and cuts of hip rafters on a pitch of 45°, the principle is the same in all pitches. Take the run and rise of the common rafter on both tongue and blade, and measure across, and the length of the common rafter is ascertained. Take the run on both tongue and blade, and measure across, take the distance obtained on the blade and the rise (12 inches) on the tongue, and measure across again, and the length and bevels of the hip rafter are found. The above is to 1-inch scale.

Again, by taking 12 on both tongue and blade and measuring across, the actual length of rafter for 1-foot run is found. Take 17 on the blade and 12 on the tongue, and measure across, and the length of hip rafter for 1-foot run of common

rafters is found; that is—if, say, the half-width of the building is 15 feet, take for the length of the hip the length of 1-foot run 15 times, which is always 17 on the blade, and the rise for 1 foot on the tongue. If the instructions given are followed anyone will be able to get all the cuts, lengths and bevels for a roof of any pitch whatever.

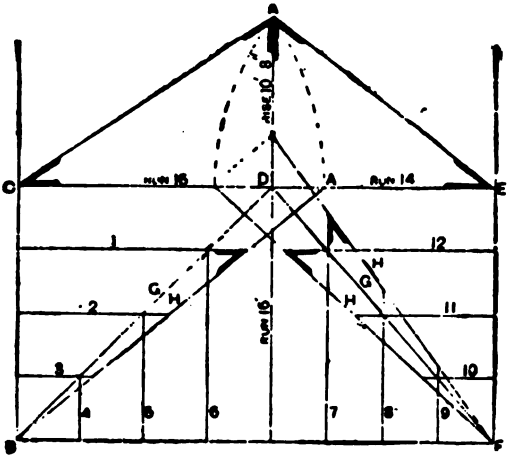


FIG. 34

Supplementing the foregoing it may be said that the line diagram, Fig. 34, shows the plan of one end of a hipped roof, the elevation of a pair of common rafters, and the development of the four quarters of the hip. These will be sufficient to show clearly how the steel square is applied.

As both sides of the hip are alike, I have on th left side of the hip developed only one side. Th process is as follows: First drop the point of th common rafter A to A', and draw a line from it to corner B. If this diagram is made on cardboard to a scale of ¼ inch to 1 foot, and the triangle formed cut through with a penknife from A' to B, and from A' to C, leaving from C to B as a hinge, also cutting through the lines from C to A, and from A to E, and folding this up on the line C to E as a hinge, raising the other triangle up and letting it rest on the first, one side of the hip will be represented in the position it would occupy when fixed; the points A and A' would stand plumb over the point D. Now apply the steel square, and note its position. Lay the tongue on the line C to B, which equals the run, and the blade on the line C to A, which is the length of the common rafter, while from B to A' is the length of the hip rafter. Marking alongside the blade, it will be seen, must always give the bevel for jack rafters. The numbered lines represent the jack rafters.

On the right side of the hip both quarters are developed, because the run of one is 16 feet, and that of the other 14 feet. Now note the difference in the application of the square. Take the

in of the common rafter on the end, on the ongue, that is, from E to F (not from E to D), nd the length of the common rafter on the right n the blade, and mark by the blade. This ives the top cut or bevel for the jack rafters on he right. Now take the run of the common after on the right side—that is, from D to E on ie tongue, and the length of the common rafter i the end (which is the same length as on the ft side) on the blade, and mark by the blade. his gives the top cut of the jack rafters for the d. If the triangles are cut and placed in posi-ons as suggested for the other side, the correct-ss of the measurement will be demonstrated. he length and bevels of the hip on the right le are obtained by taking the run of the end 5 feet) on the blade, and the run of the right le (14 feet) on the tongue, and measuring ross, then taking the length thus obtained hich is the run of the hip rafter) on the blade nd the rise (10 feet 8 inches) on the tongue, and easuring across, which gives the length, and kewise the bevels, of the hip rafter. G indi-ates the run of hip, and H the length of hip.

The following is a useful application of the teel square: On the left of diagram, 8 and 12 nches on the square, cut the common rafters; if

it rises 8 inches in 1 foot it will rise 10 feet 8 inches on 16 feet. Using ¼-inch to 1 foot scale, place the square on the line (Fig. 35) at 3 and 2,

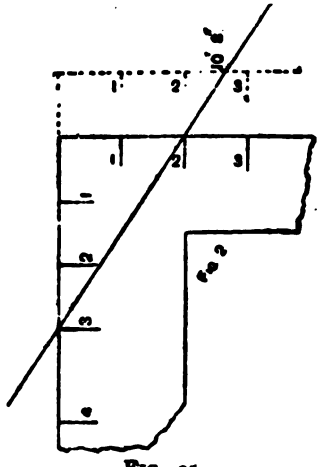


FIG. 35

representing the 12 feet 8 feet. Now slide the square up, to bring 4 on the line, as shown by dotted lines, which gives 10 feet 8 inches rise in 16 feet, which may be stated thus,—12 : 8 :: 16 ft. : 10 ft. 8 in. It will be seen that the steel square, as a mechanical device, will solve problems both in square root and simple proportion.

Perhaps the following examples on the subject which were submitted by correspondents to "Carpentry and Building" may prove useful to my readers, as they contain several good ideas which are worth considering. I have made some slight

changes in the text in order to make it suitable to these pages, but this does not affect the subject-matter in the slightest: In the lay-out shown at Fig. 36, we have a 3x6 valley rafter and find

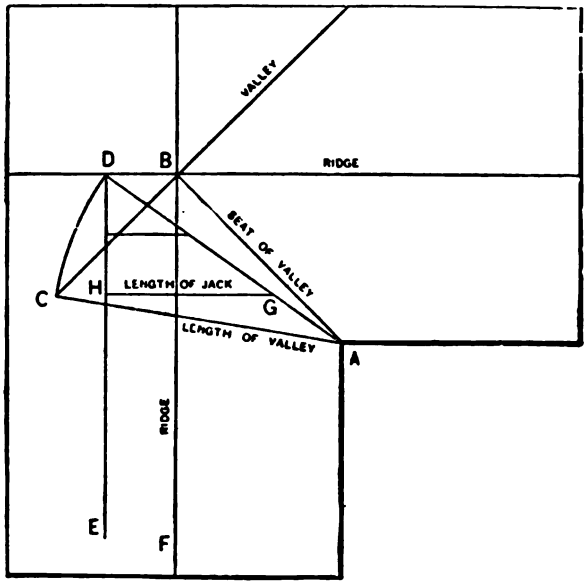


FIG. 36

the center of the face side at the point A, where it intersects the two ridges, as shown in Fig. 37, the center line being AB. Now measure one-half the thickness of the rafter—that is, 1½ inches from A, which gives the point C. Squaring across gives the points D and E. Connecting the points A, D, and E gives the angle cut

where the ridges meet at D, as shown in sketch. It must be evident that if C is raised to stand directly over B we get the angle or slope of the valley rafter, also the angles of bevels. In the

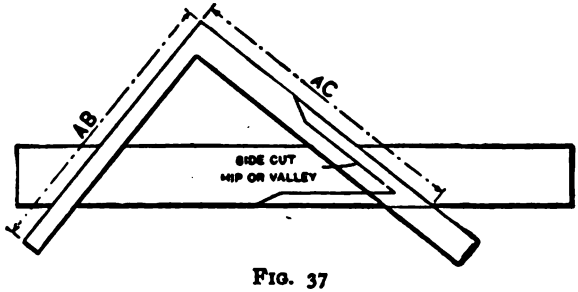


FIG. 37

diagram shown at Fig. 37, the square is set to show the method of getting the proper cuts and lengths, AB shows the horizontal line or seat of valley, while AC shows the run or length of valley rafter. CB on diagram, Fig. 36, shows the rise of the rafter. If the distance CB be used on the tongue of the square, and AB, the seat, set off on the blade, these will give the plumb and bevel cuts of the rafter; while the bevels shown in Fig. 37 give the cuts for *sides* of hip or valley.

FIG. 38

A plan of the valley rafter as laid off for cutting bevels, is shown at Fig. 38.

Fig. 39 shows position of rafter where ridges meet.

Fig. 40 shows an elevation of the valley rafter in its proper position on the wall plates. We will suppose that the rise is 9 inches to the foot run, as shown, in which case the hy-

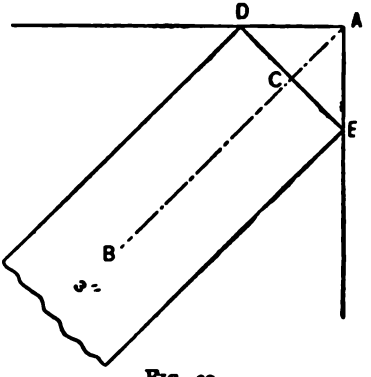


FIG. 39

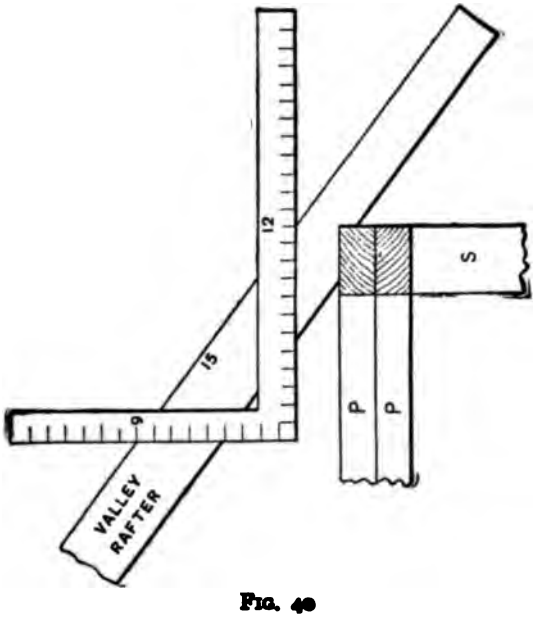


FIG. 40

pothenuse or line of rafter is 15 inches to 1-foot run. Fig. 41 shows the method of obtaining the

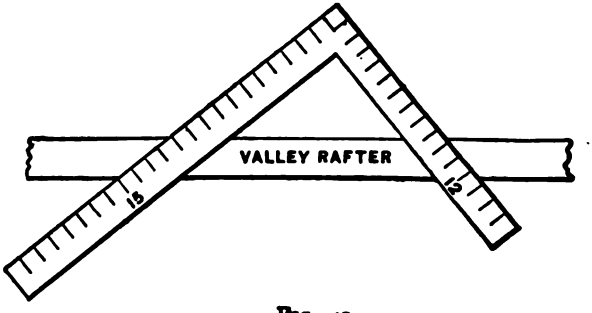


FIG. 41

bevel. Take 15 on the blade and 12 on the tongue of the square, place it on the rafter as shown, and the tongue will give the desired bevel, marking along the blade. In order to frame a rafter against two ridge boards running at right angles, draw a line in the center of the rafter and reverse the square. This rule works on all pitches.

Again, suppose the half-width of a roof having a pitch of 45° is 10 feet, and that an adjoining roof is one-third pitch, then it will take 15 feet of it to make an equal rise. By the conditions of the problem we then have a rectangle 10x15 feet by which to get the length of the valley rafter sought. A line drawn diagonally through this rectangle will give the run of the valley

rafter. Lay off at right angles each way from the diagonal a distance equal to the rise, Fig. 42,

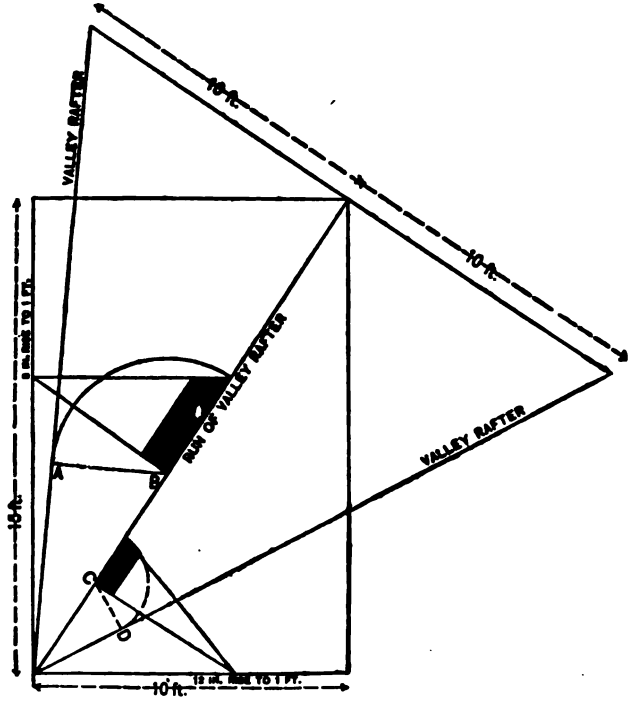


FIG. 42

and connect it as shown in the diagram. This will give the length of the valley rafter. Let fall on each side of the diagonal a perpendicular equal to the half-width of the rafter terminating at the sides of the figure. From B and C thus established let fall perpendiculars BA and CD

from the line of the valley rafter. Then AB will be the backing or distance above the edge of valley to set the jacks for the 45° pitch, and

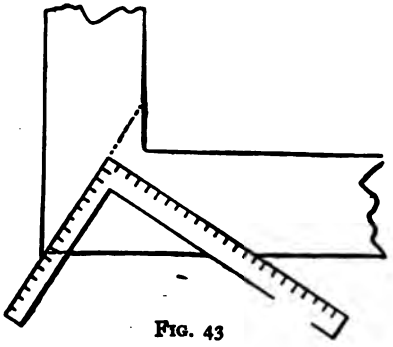


Fig. 43

CD will be the height above the edge of valley to set the jacks for the third pitch. The line on the plate will be obtained as shown in Fig. 43, using the square with 10 on the tongue and 15 on the blade.

From W. H. Croker, of Orillia, Ont., who is

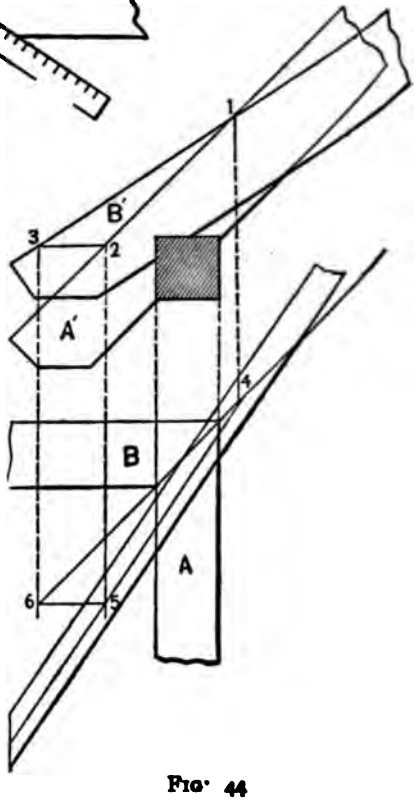


Fig. 44

an excellent authority, I get the following on the same subject: Suppose the plan of the plates is AB, Fig. 44, in any given building, and the corresponding rafters A'B'. Where the top lines of rafters intersect, marked 1 on the elevation, drop a plumb line 14 to intersect 4-6, made at an angle of 45°, and passing through the internal angle of the plates. At any point eaveward draw 2-3 horizontal, and from the point of intersection 3 drop the plumb line 3-6, and from where it intersects the line 4-6 draw 6-5 parallel to 2-3. Make 6-5 equal to 2-3. Then a line drawn as shown by 5-4 will be the plan of the center of the valley rafter. One-half of the thickness of the rafter laid off on each side of 4-5 will determine the relative position of the valley rafter to the plates. In order that the student of this work may be armed with the proper theory underlying the formation of hip roofs, I submit the following, which is taken from Peter Nicholson, whose methods for finding "working lines" in timber framing have never been excelled.

Let *abcd*, Fig. 45, be the plan of a roof, *wy* the width or beam, *ix* the height of the roof, *wx* and *wy* the length of the common rafters; to find the length of the hip rafters from the data here given proceed as follows:

Bisect each end of the plan *ab*, *cd*, in the points *r* and *q* and draw the plan *qr* of the ridge line.

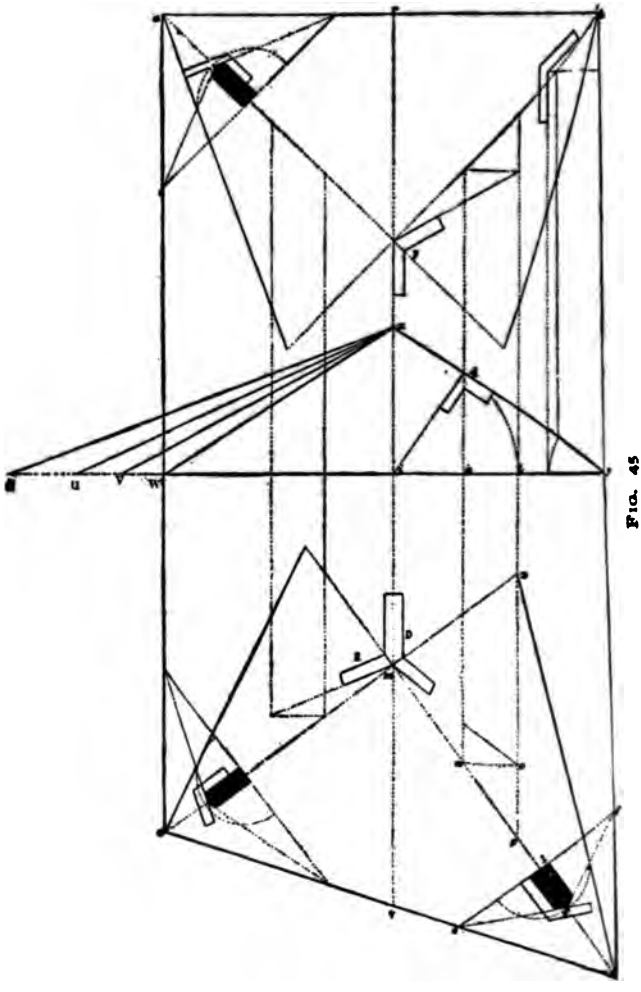


FIG. 45

Bisect the angles at *a*, *b*, *c*, *d* of the roof, by the nes *as*, *bs*, *cm*, *dm*, meeting the plan of the idge line in *s* and *m* and the lines *as*, *bs*, *cm*, *m* are the plans of the hip rafters. From the oint where the plans of the hip rafters meet the idge line, draw a perpendicular to each of the ip rafters, and set the height *ix* of the roof pon each perpendicular; and the hypothenuse f each right-angled triangle will be the length f each hip rafter. Thus find the hip rafter ver *dm*: Draw *mz* perpendicular to *dm*; make *iz* equal to *ix*, and join *mz*; then *mz* is the length f the principal rafter over *dm*.

The hip rafter may be found very conveniently n the following manner: Produce *iw* to *t*; ake *it* equal to *md*, and draw *tx*, which will be qual to *dz*; and thus the remaining three will e found. To find the backing of the hips, draw *f* at right angles to *md*; from the point *l* as a enter find the radius of a circle which will touch he line *dz*; make *ig* equal to that radius, and oin *gf* and *ge*; then the angle *egf* is the angle f the back of the rafter. This method of find- ng the backing of hip rafters is said to be the nvention of a Mr. Pope. In this illustration and escription almost every possible shape of hip oof plan is involved, and from it hips and

jacks may be determined with their lengths, bevels, and inclinations, without much trouble.

It will be noticed that the steel square is not employed in this description, or in the illustration. This is due to the fact that Mr. Nicholson's works were published long before the American steel square came into general use. This illustration is the most complete of its kind known, and this is partly my excuse for its reproduction in this work.

UNEVEN PITCHES

Irregular, uneven, or unequal pitches, are simply different pitches in the same roof. When they are the same on all sides and the building is square, the hips or valleys run in from the corners at an angle of 45 degrees, regardless of the rise of the roof; but should one side be steeper than the adjoining side, or the gables be of different pitch from the main roof, then the hips or valleys depart from the 45° angle.

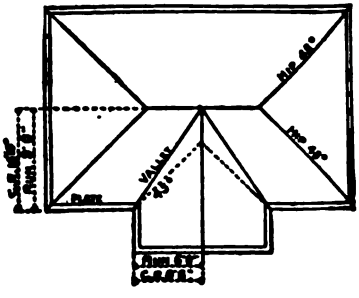


FIG. 46

Fig. 46 shows a roof plan with the one-third pitch on the main part, with a half-pitch gable. The seat and down cuts of the jack and common rafters remains the same as in the even-pitch roof, except the top cut of the jack.

I will not take up space to explain this cut at length, but will give that obtained by the square as follows: Take to scale the length of the left common rafter, on the blade and the run of the right common rafter on the tongue.

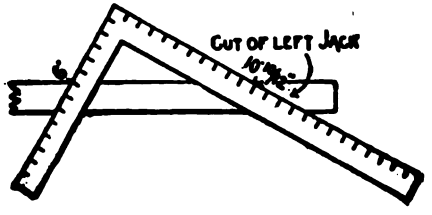


FIG. 47

Blade gives the cut of the left jack—*vice versa* for the right jack. Figs. 47 and 48 illustrate these cuts.

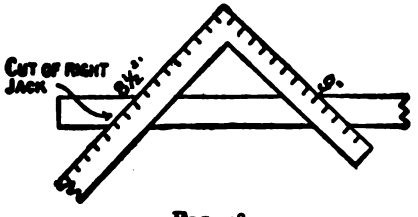


FIG. 48

Here is another problem that comes in con-

nection with the uneven-pitched roof. Where a projecting cornice is desired, with planceer, the valley will not rest at the angle of the plate, but at a point in line with the intersection of the cornice, as shown.

This necessitates the plate on the steeper pitch being raised as much as the difference in the rise of the pitches in the width of the cornice.

Thus, if the cornice be 18 inches wide, the rise of the half-pitch is 18 inches, and that of the one-third pitch is 12 inches, a difference of 6 inches. Therefore, the proper height of the plate above that of the lower pitch is 6 inches.

In connection with the above, Mr. Woods gives the following explanations and diagrams for finding the lengths of rafters where the rises in the roof are of different heights. For example, we will suppose the main gable, Fig. 49, to be 24 feet wide with a 14-foot rise, and the side gable to be 16 feet wide with a 10-foot-8-inch rise. In a case of this kind it is better to let one of the valleys extend on up to the ridge board of the main gable and let the other valley rest against it (the long valley). But how to locate them on the square is the main question. 1st. Place the squares as shown. On square No. 1 lay off the

run and rise of the wide gable, and the same for the narrow gable on square No. 2.

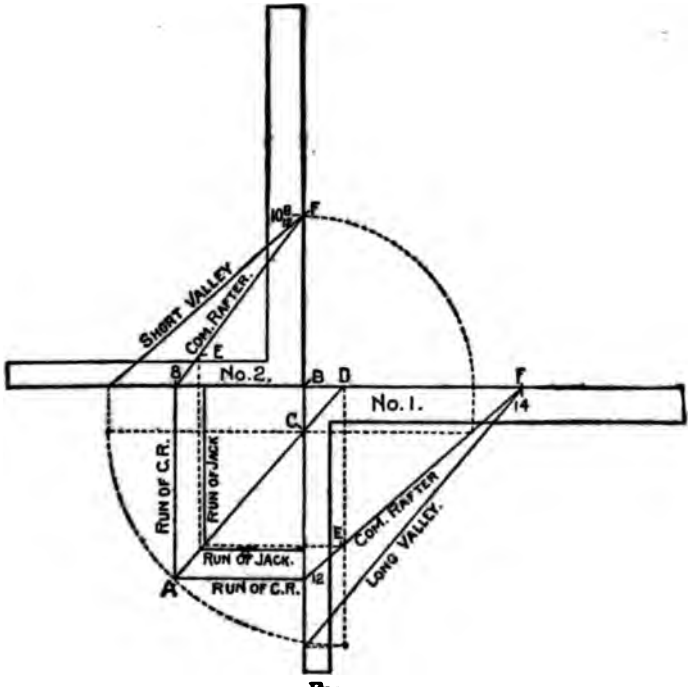


FIG. 49

2d. By connecting the run and rise, as shown by the diagonal line, on each of the squares will be the length of the common rafter.

3d. Square out from the tongues as shown, till they intersect at A, which will be the runs of the gables or of the common rafters.

4th. Set compass at B, and open to equal the

rise of the narrow gable and swing to the blade of No. 1, and square in to the common rafter, thence run an imaginary line parallel to the blade, and where it intersects the tongue establishes the point where the ridge of the narrow gable dies or intersects on main roof and which point I will call C.

5th. A line drawn from A to C represents the run of the short valley, and by extending the line on to the blade of No. 1 establishes point D, from which to B represents the run of the long valley, and these lengths taken on the tongues as shown, and connected with their respective rises, will be their lengths.

6th. The lengths of the jacks are found as shown from E to F, which I trust is clear enough without further explanation.

The cuts and bevels are all contained in this diagram.

GENERAL ITEMS

On the subject of roof framing, Mr. Stoddard says: "I have given some thought and study to roof framing, and have concluded the square is master of the situation, as it is much quicker and less liable to mistake than any method I know of."

Let us take the number of inches the roof is to rise to the foot on the tongue and one foot on the blade (which is the rise and run of one foot). If the building is 14 feet wide at a 7-foot run,

FIG. 50

apply seven times, as illustrated in Fig. 50. To cut octagon rafter, apply same as common, except use 13 inches in place of 12 inches on blade, hip or valley, use 17 inches.

To cut jacks, if you wish them 16 inches apart, slide the square up to 16 inches; if 20 inches, slide up to 20 inches, and so on.

The *rise* and *run* cut on rise gives top cut and all plumb cuts; the run gives cut on plate and all level cuts.

The side cut of jacks to fit hip, and valley to fit ridge, etc., is *length* of *rafter* and run, cut on length.

These general rules apply to all roofs, and this is roof framing in a "nut-shell," although it may not be new, original, or even the best.

But a better way yet is to take rise and run, measure across and get length of rafter; this gives length of all rafters for even or uneven pitches, and all main cuts, which is a very impor-

tant matter and saves much trouble and worry where unequal pitches are to be worked out.

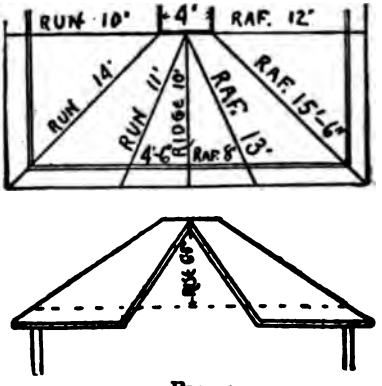


FIG. 51

To illustrate this I will take a little 24-foot cottage, one-third pitch hip roof, 4-foot deck and gable in front. See cut, Fig. 51.

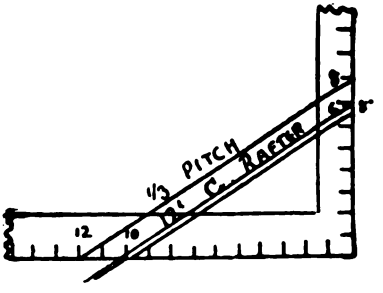


FIG. 52

As it is only the principle involved, for convenience in illustrating we will use even feet as much as possible, and not give accurate measure

ments as to inches, although in real framing accurate measurements should always be made.

One-third pitch roof rises 8 inches to the foot. As this 24 foot house has a 4 foot deck, the run of common rafter would be 10 feet, as the rise is 6 feet 8 inches and the run 10 feet, the length of common rafter is 12 feet, Fig. 52.

As the run of the hip is the diagonal of 10 feet

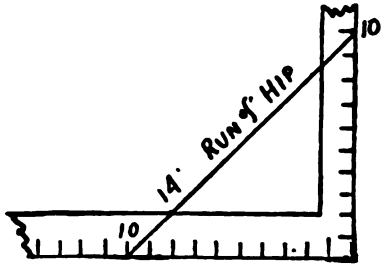


FIG. 53

or 14 feet, Fig. 53, and the rise is 6 feet 8 inches, run 14 feet, length of hip is 15 feet 6 inches, Fig. 54.

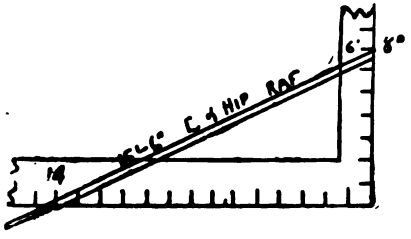


FIG. 54

If the jacks are to be 16 inches apart, measure across your square at 16 inches, at one-third

pitch, and you have 19 inches, Fig. 55, length of short jack; twice that length is length of second

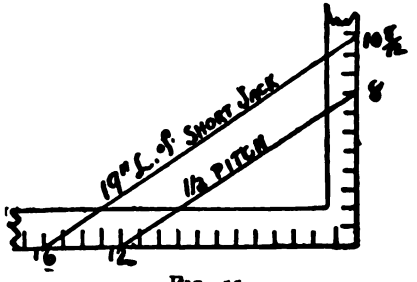


FIG. 55

ones, and so on; or divide the common rafter into the number of jacks required and get your lengths from common rafter.

As the length of common rafter is 12 feet and run 10 feet, place the square on 12 and 10; cut on 12 for bevel of jack rafter, Fig. 56.

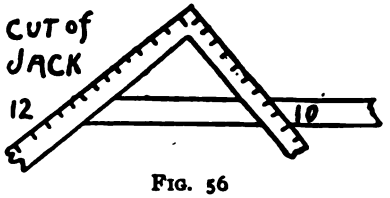


FIG. 56

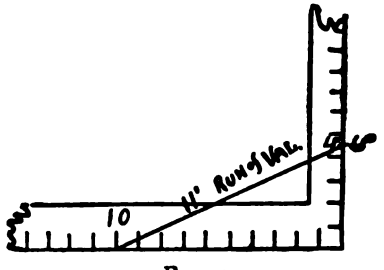


FIG. 57

Now, as the front gable is to show the roof,

divide into about three equal parts, allowing for projections; set the foot of valley 4 feet 6 inches from center of building, as it runs back 10 feet to deck.

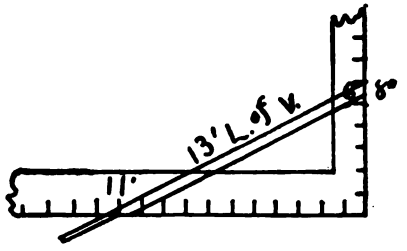


FIG. 58

The run of valley is 11 feet, Fig. 57; as the rise is 6 feet 8 inches, run 11 feet, length of valley rafter 13 feet, Fig. 58.

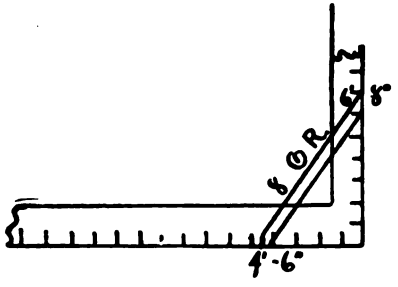


FIG. 59

As the rise of front gable is 6 feet 8 inches and run 4 feet 6 inches, length of gable rafter 8 feet, Fig. 59.

As the length of common rafter on main roof

is 12 feet and run of gable 4 feet 6 inches, place the square on length and run cut on length, and

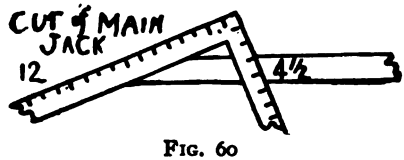


FIG. 60

it gives side cut of main jack to fit valley, Fig. 60.

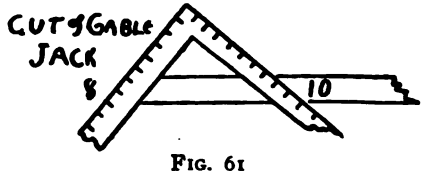


FIG. 61

As the gable rafter is 8 feet and run of main roof 10 feet, length and run cut on length gives side cut of gable jack, Fig. 61.

Most workmen who have followed all the examples given in this work are aware that the rise of the valley or hip taken on the square will give the seat and plumb cuts, but to cut the seat so that the top edge, backed or unbacked, will coincide with the plane of the common rafter is a problem that many are not so sure of; but go ahead and make the cut, trusting to luck, and if it doesn't come right, block up or cut down as the case may be, and the matter is dismissed for the time, only to reoccur on the next job.

In order to enable the workmen to get positive results, the following illustrations and text are submitted; they have appeared before in a different shape, but, as I stated in the outset, it is my intention to publish in this work everything that in my judgment, will be of service to the reader and that is in anyway connected with the use of the steel square.

The illustration shown at Fig. 62 exhibits the position of a hip or valley rafter when the roof is of equal pitch. A, being at the corner of plate for either a hip or valley. If the former, its sides will intersect the edge of the plate at B and B, or at C and C, for the latter.

The distance from A to B and B, or C and C, is always equal to the diagonal of a square with sides equal to one-half the thickness of the rafter. If the rafter be 2 inches, then the distance will be $1\frac{5}{8}$ inches. BC (along the side of the rafter) is equal to the thickness of the rafter, and this measurement taken square out from the plate at BC', and by transferring the center as *a*, will give the different positions of the seat cuts with that of the common rafter.

Now passing up to the common rafter, DE is the depth desired from the plate to the top edge of the rafter.

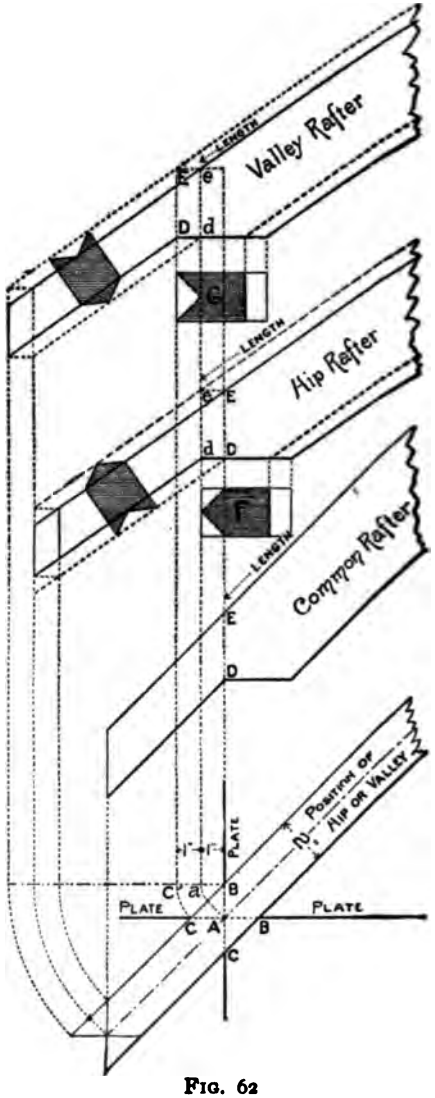

Valley Rafter
LENGTH
e
D
d
G
Hip Rafter
LENGTH
E
d
D
F
Common Rafter
LENGTH
E
D
Position of Hip or Valley
PLATE
PLATE
PLATE
C
a
B
C
A
B
C

FIG. 62

Passing on to the hip. If the same is not to be backed, DE will be the same as of the common rafter, but the seat cut will extend to *d* on the *a* line, but if to be backed, *de* will be the depth and will equal DE when backed where the sides of the rafter pass over the edge of the plate at BB. The face view of the seat would show as per the shaded part of section at F.

Passing up to the valley, the depth above the plate at A will be *de*, backed or unbacked. The seat cut will extend to D at the sides, and will intersect the plates at CC.

If to be backed, DE will be the depth above plate at CC. The shaded part of section at G, shows the face of the seat cut in case the under side of the tail is backed; however this is generally omitted. The reader will understand that like letters represent like measurements. DE being over the plate at B or C, and *de* over A. The solid lines represent the rafters when not backed, and the broken or dotted lines when backed. From this it will be seen that the backing of a hip or valley is obtained by setting off one-half of its thickness on the seat bevel, as at *e* E, or *d* D.

In Fig. 63 is shown the plan of a hip and common rafter in place, also an elevation of same

with the hip swung parallel to the common rafter, AC and AB being their respective lengths.

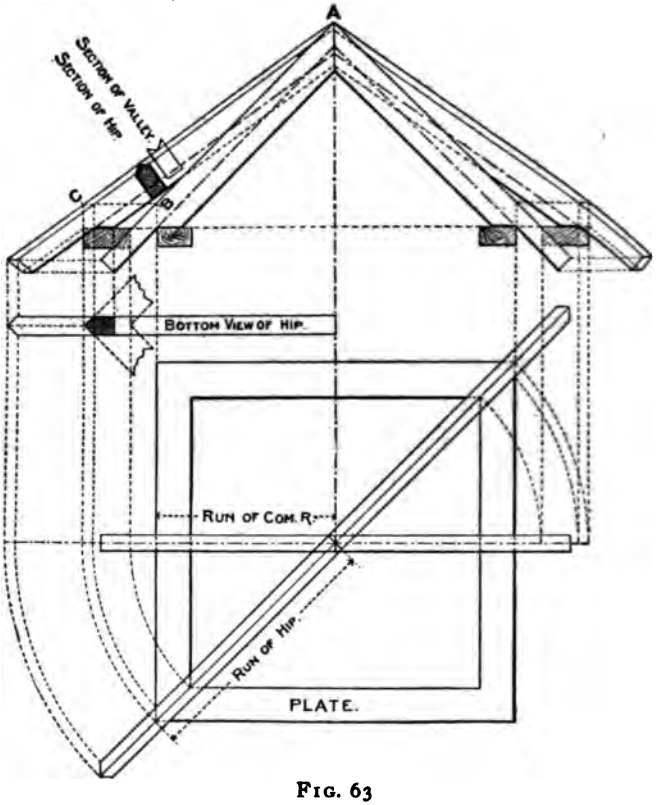


FIG. 63

A method of laying out a hip roof and making a cardboard model for same was published in "Carpenter," some time ago by Mr. Henry D. Cook, of Philadelphia, Pa., and which is repro-

duced here, as I think it worthy of a place in the present work.

The most simple form of hip roofs is that where the ground plan of the building makes right angles. In the ordinary hip roof but little constructive skill is required, the only points requiring particular attention are in finding the proper lengths and side cuts of jack rafters, and those can be made quite simple. To do this, suppose we get a piece of cardboard and commence laying down the ground plan of a building, which we will represent by letters A, B, C, D. Next lay out the elevation of one pair of rafters B, E, C, shown at A, Fig. 64. Next lay down the seat of the hip at an angle of 45°; on each side set off half thickness of hip which draw parallel with center line AF; from the seat line AF square out from F to G; make GF in A, Fig. 64, equal HE in the same diagram, and square out lines IJ and KL, and join AG, which gives the back line of the hip rafter; next lay off the seats of the jack rafters on line AD, and make MN equal the given rafter BE or CE, and join D, N, on each side of which set off half thickness of the hip; next square over the seat lines of the jacks on line AD, and let them cut the seat of hip as represented on the plan; then with

your dividers take D as center and M as radius, and strike the curve line cutting at O, make ON

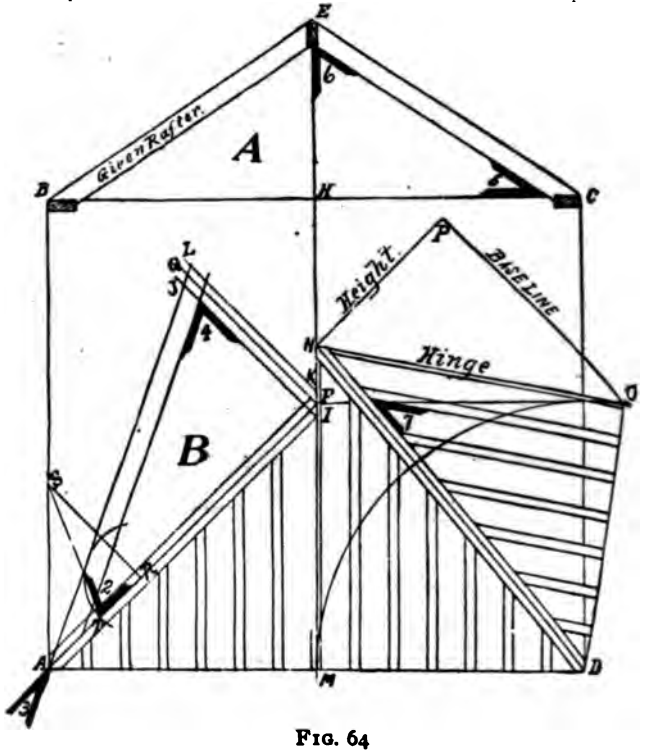


FIG. 64

equal MN, and make OP equal OD, and PN equal HE, in A, Fig. 64, and lay off your jacks on line OD. Now with one point of your dividers press it through at center point, A, also at F; from these impressions on back side of card, and with a sharp-pointed knife, cut partly through

the cardboard only. And from A to G, and G to F, on face side cut clear through the card; the hip is now ready to raise; the line AF will form a hinge; but before doing this turn your attention to center line at M; on this line you will cut through from M to N, and on line from D to O you will cut clear through, from O to P will also have to be cut clear through, and on line from P to N must be cut through.

Next, on line NO, on face side, cut partly through only, as this must form a hinge when you begin to turn up the work; next on center line ND, on face, cut partly through only, and on line from M to D cut partly through from the back.

You are now ready to raise this section of the roof. Now, at point N, commence to raise up your work, and you will notice as you raise the point N the point P will fall and will stand at letter F, and the point at O will swing around and stand on line CD. You will then have a perfect model of one corner of the roof of the building, and at the same time the hip will show its perfect backing.

Next come to AG and raise or turn up the hip, and see how nicely it agrees with the other portion of the roof; two hips will come together when points N and G will meet.

You can go still farther by pressing the point of your dividers through points B and C, and from these impressions on back cut partly through the card only, and on lines BE and EC you will cut clear through; you are now ready to raise the given rafters, which should stand at a right angle with the cardboard, when it will be seen that the backs of the given rafters, also the jacks and the hip, all agree and will all be on a straight line.

Backing the hip at any point on the seat, say R, square out a line cutting line AB at S; take R as center, and a circle cutting back of hip, also center of seat at T, join ST, which gives bevel 2 for the backing. The bevels for the plumb and foot cuts of the hip are seen at 3 and 4, and the bevels for the plumb and foot cuts of the given and all the jack rafters will be seen at 5 and 6, and the bevel for the side cut or face of the jacks will be seen at 7.

To cut the hip so as to fit against the ridge, you will notice the points J and L, in B, crossing the line of the hip at the point L, will be the longest point of the hip, and at point J, square over the back of hip and marked on the other side, gives the shortest cut. As all measurements are taken from the center, one-half thick-

ness of the ridge will yet have to be taken off at the upper end.

The construction of a model roof in cardboard, after the method as advanced in the foregoing, will materially assist the workman in grasping the true principles of roof framing, and enable him to understand the reasons "why and wherefore" all the necessary lines for laying out such a roof as described may be obtained by an intelligent application of the steel square.

Before leaving the subject of ordinary roof framing, I wish to reproduce from "Modern Carpentry" an extract from an English source, which deals with roof framing somewhat different to American practice. I have changed and amended the text somewhat in order to make it more easily understood by American workmen. In order to give a general idea of the use of the square there is herewith appended a few illustrations of its applications in framing a roof of, say, one-third pitch, which will be supposed to consist of common rafters, hips, valleys, jack rafters, and ridges. Let it be assumed that the building to be dealt with measures 30 feet from outside to outside of wall plates; the toe of the rafters to be fair with the outside of the wall plates; the pitch being one-third (that is, the

roof rises from the top of the wall plate to the top of the ridge one-third of the width of the building, or 10 feet); the half-width of the building being 15 feet. Thus, the figures for working on the square are obtained; if other figures are used, they must bear the same relative proportion to each other.

To get the required lengths of the stuff, measure across the corner of the square, from the 10-inch mark on the tongue to the 15-inch mark on the blade, Fig. 65. This gives 18 feet

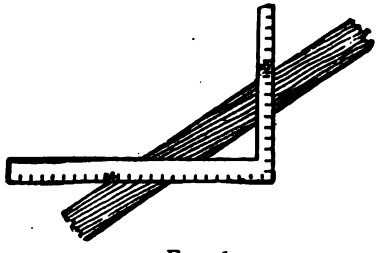


FIG. 65

as the length of the common rafter. To get the bottom bevel or cut to fit on the wall plate, lay the square flat on the side of the rafter. Start, say, at the right-hand end, with the blade of the square to the right, the point or angle of the square away from you, and the rafter, with its back (or what will be the top edge of it when it is fixed) toward you. Now place the 15-inch mark of the blade and the 10-inch mark of the

tongue on the corner of the rafter—that is, toward you—still keeping the square laid flat, and mark along the side of the blade. This gives the bottom cut, and will fit the wall plate. Now move the square to the other end of the rafter; place it in the same position as before to the 18-foot mark on the rafter and to the 10-inch mark on the tongue and the 15-inch mark on the blade; then mark alongside the tongue. This gives the top cut to fit against the ridge. To get the length of the hip rafter, take 15 inches on the blade and 15 inches on the tongue of the square, and measure across the corner. This gives $21\frac{1}{16}$ inches. Now take this figure on the blade and 10 inches on the tongue, then measuring across the corner gives the length of the hip rafter.

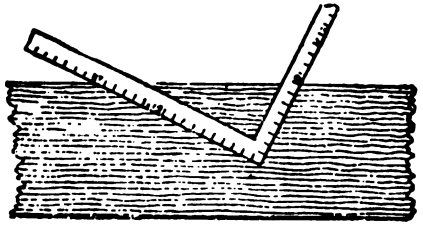


FIG. 66

Another method is to take the 17-inch mark on the blade and the 8-inch mark on the tongue and begin as with the common rafter, as at Fig.

66. Mark along the side of the blade for the bottom cut. Move the square to the left as many times as there are feet in the half of the width of the building (in the present case, as we have seen, 15 feet is half the width), keeping the above-mentioned figures 17 and 8 in line with the top edge of the hip rafter; step it along just the same as when applying a pitch board on a stair-string, and after moving it along 15 steps, mark alongside the tongue. This gives the top cut or bevel and the length. The reason 17 and 8 are taken on the square is that 12 and 8 represent the rise and run of the common rafter to 1 foot on plan, while 17 and 8 correspond with the plan of the hips.

To get the length of the jack rafters, proceed in the same manner as for common or hip rafter; or alternately space the jacks and divide the length of the common rafter into the same number of spaces. This gives the length of each jack rafter.

To get the bevel of the top edge of the jack rafter, Fig. 67, take the length, 14⅜ inches of the common rafter on the blade, and the run of the common rafter on the tongue, apply the square to the jack rafter and mark along the side of the blade; this gives the bevel or cut. The down

bevel and the bevel at the bottom end are the same as for the common rafter.

To get the bevel for the side of the purlin to fit against the hip rafter, place the square flat against the side of the purlin, with 8 inches on the tongue and 14⅜ inches on the blade, Fig. 68. Mark alongside of the tongue. This gives the side cut or bevel. The 14⅜ inches is the length of the common rafter to the 1-foot run, and the 8 inches represent the rise.

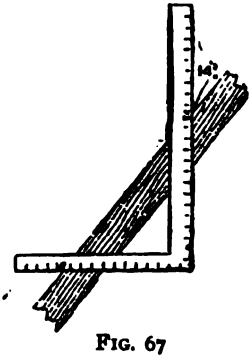


FIG. 67

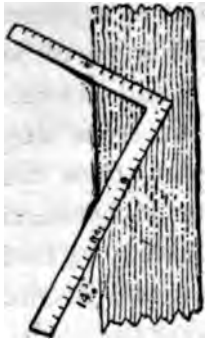


FIG. 68

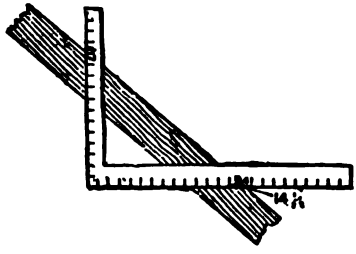


FIG. 69

For the edge bevel of purlin, lay the square flat against the edge of purlin with 12 inches on the tongue and 14½ inches on the blade, as at Fig. 69, and mark along the side of the tongue. This gives the bevel or cut for the edge of the purlin.

The rafter patterns must be cut half the thickness of ridge shorter, and half the thickness of the hip rafter allowed off the jack rafters.

A few remarks regarding the backing of hip rafters and the getting of the proper lengths of jack rafters, or "cripples" as they are called in some sections of the country, and I have done with ordinary roof framing for the present.

I have shown in several instances how the lengths of jack rafters and their bevels may be obtained, but I have not specially shown how these results are obtained, so will devote some little space now to this purpose. Let us suppose AB and BC, Fig. 70, to be hips, and AD and CD valleys laid out from any particular plan, then the jacks cutting in between valley and hip may be laid out as shown at FE; the bevels showing the angles of the cuts, the plumb cuts being the same as for common rafters. The bevel at E shows the side cut against the hip, and the bevel at F the side cut against the valley rafter.

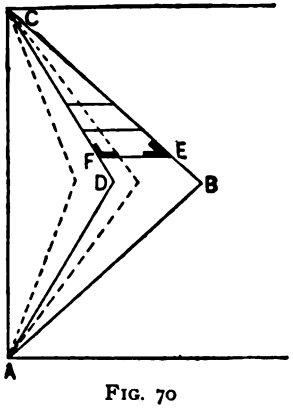


FIG. 70

Another way to determine the length of jack rafters is given as follows: On the steel square, take 12 inches on the blade and the rise of the roof, 12-foot run, on the tongue, and measure the distance across. This length in inches, multiplied by the number of feet the jack rafters are to be on centers, will give the required length in inches. For example, if the roof rises 11 inches per foot run, measure the distance from 11 on the tongue to 12 on the blade of the square, which is 16¼ inches. Now, supposing the jack rafters to be 16 inches, or 1⅓ feet on centers, we have 16¼ x 1⅓ = 21⅔ inches, which is the difference in the lengths of the jack rafters.

The lengths may also be found by first getting the length of the common rafter in inches for a 12-inch run, and multiply this by the distance in inches the jack rafters are to be from center to center, and divide the result by 12. This gives the difference in the length of jack rafters in inches. For example, if the rise is 12 inches and the run is 12 inches, the run of the rafter is nearly 17 inches. Now, 17 multiplied by 28 and divided by 12 gives 39⅔ inches. This is the difference in the length of the jack rafters for a one-half pitch roof where the jacks are 28 inches

from centers. This rule will work on any pitch of roof.

Mr. Hicks gives the following rule, in his "Builder's Guide," for obtaining the lengths of jacks, which is somewhat similar to that already shown: Take the run of common rafter on the blade, 12 inches, and the length $14\frac{1}{8}$ inches, on the tongue, and lay a straight edge across, as

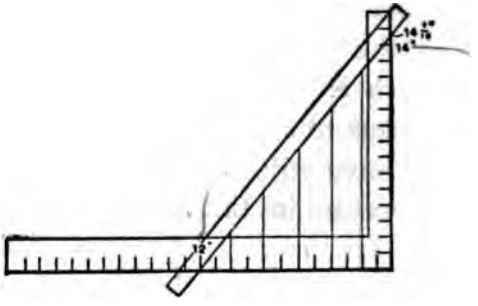


FIG. 71

shown in Fig. 71. Space the jacks on the blade of the square, which represents the run of common rafter, and measure perpendicularly from the tongue to the straight edge on the line of each jack for their length.

For cutting jacks for curved roofs, while not exactly within the scope of the steel square, yet the bevels may be laid off by that instrument as the reader will no doubt discover; so I give here Mr. Hicks' method of determining the lengths.

The curvature of these rafters will, of course, be governed by the position they occupy with relation to the hips. The method offered is not new by any means, but is presented in a manner easily to be understood by the ordinary workman. Let us suppose AD, Fig. 72, to be the run of the common rafter, DE the rise, and AE the length and work line. To find the length of jack set off the run of jack AB and square up the rise BC to the work line of the common rafter; then AC is the length of jack on the work line. This method is very simple, yet, as it is a new and novel way of finding the length of jack rafters, it will be well to point out a common mistake which the inexperienced might chance to make. Bear in mind that AE is the length of common rafter. BC is not the length of jack, as some might suppose, but the rise of jack; AC is the length of jack. The down bevel is the same as that of the common rafter. To find the bevel across the back, set off from D the length of

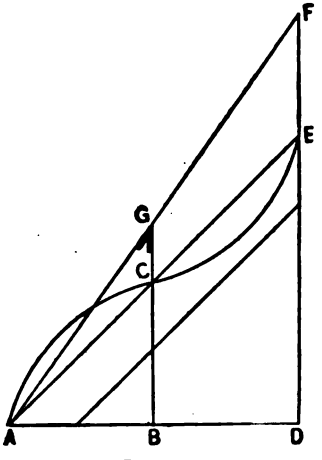


FIG. 72

common rafter to F, and connect F with A, which shows the work line of the hip. Now continue the line BC to the work line of the hip, and the bevel at G will be the bevel across the top of jack. BG is also the length of jack, and will be found to be the same as AC.

When the bevel of the jacks is known all that is necessary is to square up the rise of each jack from the base line of common rafter AD to the work line AE, and take the length from A to the point where the rise of each jack joins the work line of common rafter, as shown.

In connection with hip rafters for curved roofs, it may be well at this point to depart from the course pursued so far in the making of this book and give the ordinary lines for laying out such work without using the square for the purpose. We will suppose the lines A and B, Fig. 73, to represent the common rafter for a curvilinear roof, let B represent the common rafter, and C the valley rafter. In plan and profile, respectively, the curves of common rafters being given, first determine the seat, or base line, of valley rafter, which in roofs of this kind is curved. To illustrate, the common rafters were cut and put up on both sides of valley strips, tacked on one

side parallel with eave or ridge, and the same number of strips on the other side, tacked in the same manner and at the same vertical height; it

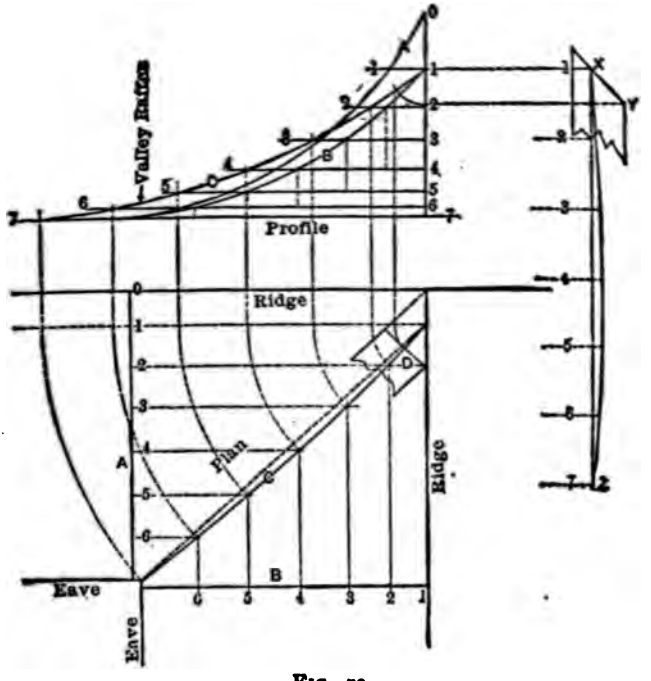


FIG. 73

is evident that their intersections would represent the line of valley. Therefore, the curves of common rafters being drawn, divide, for example, B into any convenient number of parts, and through the points thus determined draw horizontal lines. The lengths of these lines are

determined by where they cut the curve of common rafter, and are set off on corresponding rafter in plan. Then draw lines parallel with eaves or ridge, as shown in the sketch, and where these lines intersect is the base line C of valley rafter. The same points of intersection project on corresponding lines of profile, giving the line of valley rafter.

To obtain the lateral curve of valley rafter, take distance on outline of valley rafter, as made by the horizontal lines already described, and draw lines, as shown, between X and Z at the right of the sketch. Draw a vertical line cutting all these lines, and set off on each corresponding line the same lateral distance as between the straight and curved base line in the plan. To find the top bevel of valley rafters, let the thickness be as shown at D in plan. Project the length of bevel by half the thickness on curved line in profile. Project the length thus found on corresponding line on upper face, as shown by XY at right of the sketch. From the two points thus determined draw a line, which will be the true bevel.

In connection with curved roofs, the following is offered as being a good method of getting the side bevels and lengths for jacks in a hipped

roof: Let CB be the top line of one of the common rafters. In the diagram, Fig. 74, CBH is supposed to stand upright on rise BC. In shape all the jacks must be some part of the length of the common rafter measured from point C. On one common rafter lying on a flat surface with marked run and rise must be laid off all the jacks showing vertical cut, also long and short top edges opposite to each other. On run make CH equal to EG, long seat line of this jack. At right angles to run draw HK, the vertical cut. Then CK is the long top edge of this jack. For the opposite short top edge draw a line parallel to the vertical cut at a distance back equal to FG taken from seat of jack. On top face of jack mark the side bevel from end of long edge to end of short edge. It is evident that when jack CK stands upright over its seat its bevelled top end will fit against the hip face which stands over BC, because long top edge of jack stands over long seat line, and short top edge of jack stands over short seat line; only if ABC is an angle of 45° does FG equal thickness of jack. For

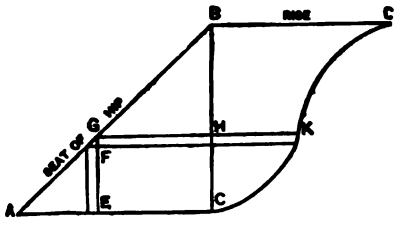


FIG. 74

each jack the side bevel will be different, but ca be obtained in this manner.

Before leaving the subject of hip, valley, an jack rafters with regard to their lengths an bevels, I think it will be in the interest of m readers to reproduce a system of lines firs

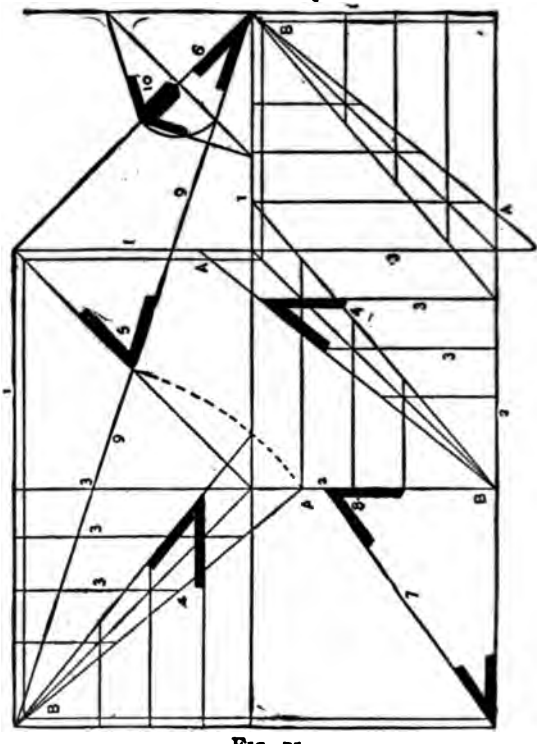


FIG. 75

invented by Peter Nicholson, and simplified by Mr. Smith and published in his "Architect," a

book that at one time had a deserved popularity. While the book is now seldom spoken of, this system of lines has been made use of by nearly all the late writers on constructive carpentry, with greater or lesser elaboration. On Fig. 75, the plan 1,1,1,1,1 represents the outside plate; 2,2, the ridge line; 3,3,3,3,3,3, the jack rafters of hip and valley; 4,4, the side bevel of jacks and the length of jack from corner of plate and ridge to side of hip and valley; 5, bevel at head of hip and valley; 6, bevel at foot of hip and valley rafter; 7 is a common rafter; 8, the bevel at head of common rafter, is the down bevel for all jacks on hips and valleys; 9,9 is the length of hip and valley rafter; 10 is the method of getting the bevel of back of hip. Draw a line at right angles with base line of hip, then set one foot of the dividers where this line crosses the base line, and the other where it crosses the hip-rafter line, and set the same distance on the base line, and draw lines from that point to the plate each way, which gives the bevel for hip, and, turned the other way up, it gives the hollow for the back of the valley. Line from *a* to *b* is the length of hip and valley dropped down to get the length of jacks. Lengths and bevels of all hips and valleys the same in same roof of same pitch.

Fig. 76 is a plan for framing a valley in a roof where one side is much steeper than the other,

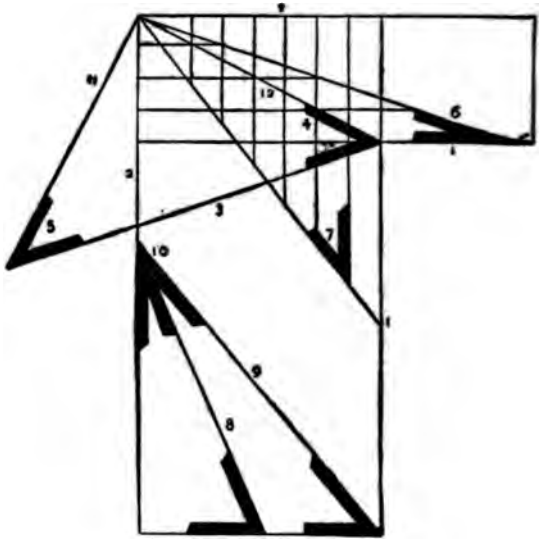


FIG. 76

as, for instance, one side rises, say, 10 feet in 8 feet. 1-1 is the wall line; 2-2 is the ridge line; 3 is the valley rafter; 4 is the bevel at the foot; 5 is the bevel at the head; 6 is the bevel of the jacks on the lowest pitch, also the length of same; 7 is the bevel of and length of jacks on the steep side; 9 is common rafter on the lower pitch; 10 is the down bevel on jacks of each side; 11 is the height of roof; 12 the base line of valley. The rafters will not match on the valley as

on an equal-pitch roof, as in Fig. 75. It will be seen that it will take seven jacks on the steep side, while it requires only four on the other side, but the bevels will all fit.

BACKING HIP RAFTERS

A writer on Building Construction has said: "In America there are more hips 'backed' in books and papers than there are in houses." Unfortunately this is too true. Most workmen never think of backing a hip; they put in the timber just as it comes from the lumber yard, with the exception of cutting the bevels for point and heel of rafters. This is all wrong. All hips *should* be backed, in order to get a good strong and nearly perfect roof. When the hip is thin, being no more than two inches thick, it is not so bad, yet it ought to be backed; but when the hip is three or more inches thick, then under no circumstances should backing be omitted.

In the present volume, as well as in the former one, I have shown some rules for getting backing for hips, but in order to have the principle well understood I present a few more examples showing how the angles may be obtained.

The method shown at Fig. 77 is a quick one, and a correct one if the measurements are

exactly taken. The diagram explains itself and requires no description. When the horizontal

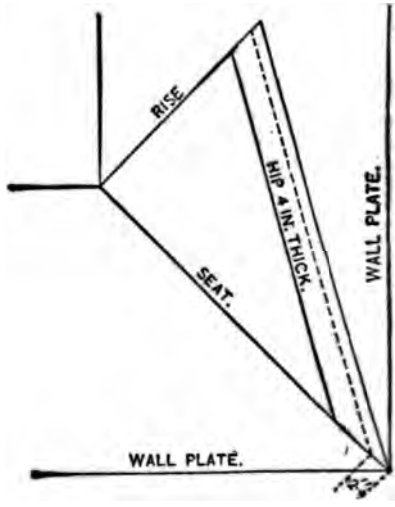


FIG. 77

or bottom cut for a hip rafter has been obtained, take one-half the thickness of the rafter and measure back from the toe or point toward the heel. This will give the point on the side of the rafter to gauge to. Then a line on the center of the top of the rafter in connection with a line gauged on the side, will give the bevel or backing.

Another example of backing and I have done. Let us suppose AB and BC, Fig. 78, to represent the plates of the building, and BD the hip rafter,

BE being the seat of the rafter. Take any point of the hip, as 1. Draw a line at right angles to

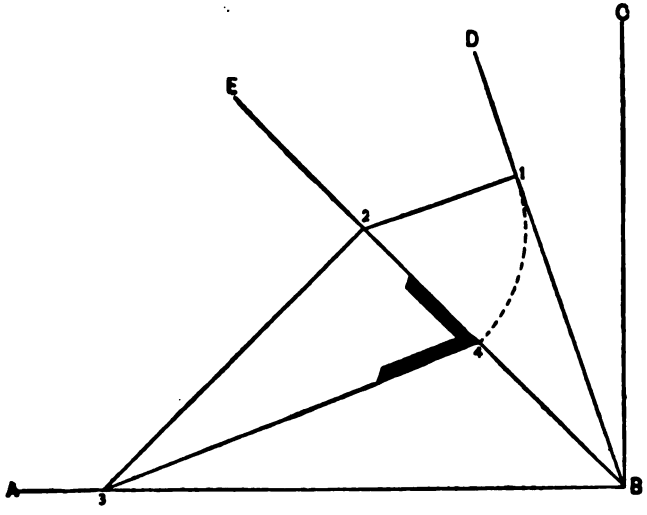


FIG. 78

this, producing it until it cuts seat BE, as shown in the point 2. From the point 2 thus established draw a line perpendicular to the seat, producing it until it cuts the line of plate AB. Transfer the distance 1-2 along the line representing the seat of the rafter, thus establishing the point 4. Draw 3 and 4; then at 4 will be given the bevel for use in backing the rafter. Fig. 79 shows the application of the bevel to the timber which will give the gauge points to work from.

These examples, with the ones on the same subject illustrated and described in previous pages, should prove quite ample and are varied enough to meet the requirements of most workmen no matter what may be their constitutional peculiarities.

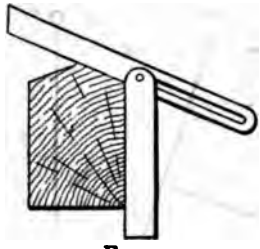


FIG. 79

FRAMING OCTAGONAL ROOFS, DOMES, BAYS AND OTHER OCTAGONAL WORK

We now enter another phase of the carpenter's art, and one in which the steel square plays, or can be made to play, an important part. I have discussed the "octagon" pretty fairly in the first volume of this work, but very much more than I have said, or can say for that matter, may be said on the construction of octagonal work; in order, however, to make this work as complete as possible I have thought it necessary to present to the reader the following illustrations and descriptions, knowing from experience they will be useful.

I have shown how the miters in polygons may be obtained by aid of the square and by other methods, and, as a sort of introduction to this chapter, I offer the following which I know will

be acceptable to many of the readers of this book who have been fortunate enough to get a fair public school education: There are three kinds of angles: the right, the obtuse, and the acute. A right angle is an angle formed by two lines perpendicular to each other. An obtuse angle is greater than a right angle; an acute angle is less than a right angle. All angles of the octagon are obtuse. A right angle is equal to 90°. The angle ABC, Fig. 80, which is one of the angles of the octagon, is 45° greater than a right angle, and is equal to 90°+45°= 135°. The octagon miter is an acute angle, and is found by bisecting 135°, which is $\frac{135}{2}$=67° 30′, which is shown at ABD.

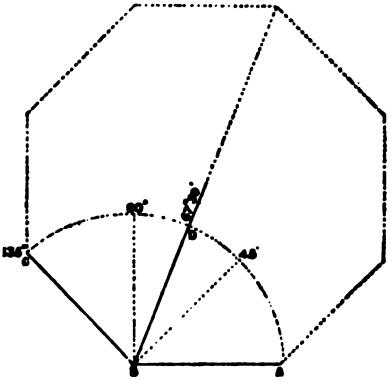


FIG. 80

I will now show the proportionate length of each line in the octagon, Fig. 81; the diameter being one, the number on each line indicates its exact length in fractional parts of one. To lay out the miter or angle, place the square as shown at ABC; take 12 inches on the blade of the

square and $4\frac{11}{12}$ on the tongue; tongue gives cut. Any other number will do as well, providing the proportion of 3827 and 1585 exists between them.

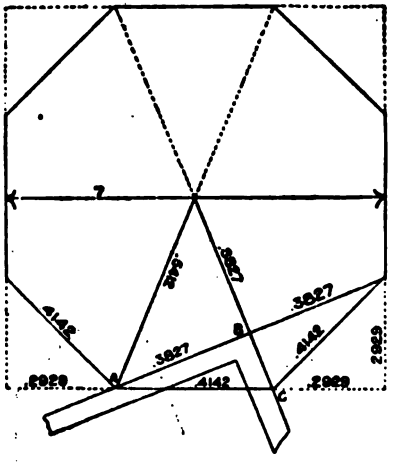


FIG. 81

This is a simple and correct method of finding the miter of an octagon, and will be found useful in solving many problems that confront the workman from time to time.

BAY WINDOWS

Often workmen are put to their "wit's end" when "laying out" an octagon bay window, owing to the surrounding conditions. The following is submitted, which shows how the faces or sides of the window or other work may be laid out with ease: First lay off a straight line DA, Fig. 82, to the length desired for one side of the window, as indicated from A to B. Then from B to C make the length $\frac{5}{12}$ of AB. The length CD is to be the same as AB. Now, with the foot of

the compasses in D, and with radius DC, strike an arc as shown. Then, with the same radius

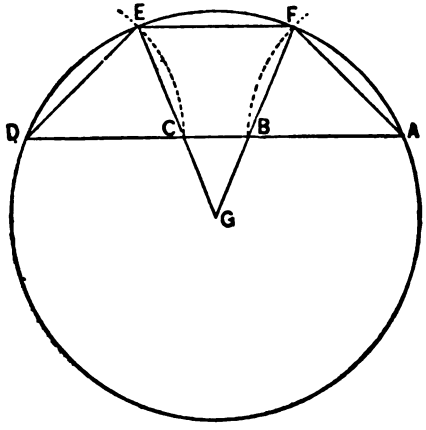


FIG. 82

from A as center, strike the second arc indicated. With the dividers set to the same distances and with C as center, strike an arc, cutting the arc struck from A, thus establishing the point F; then, in the same way, using B as center, strike an arc cutting the opposite arc, establishing the point E. Draw the lines DE, EF, and FA, the result will be three equal lengths and three equal angles. To find the center of the octagon, draw lines through the points FB and EC until they intersect in the point G; then G will be the center as required. The lines FB and EC will be the seats of hips, if any are desired. To lay off

an octagon end of building, as is often done, divide the width of the building into 29 parts, and take 12 parts for each of the extreme spaces and 5 parts for the mean space, and proceed as above. If we wish to make the front side wider than the other side—for example, 2 feet wider—deduct 2 feet from the width of the building; divide the remaining space into 29 parts, take 12 parts each for the extremes and 5 parts plus 2 feet cut off for the mean space, and proceed as above, save that in crossing the arc at E we must set the compasses 5 parts from C, or at I, all as shown in Fig. 83. And in crossing at F we set 5 parts from B, or in the point H, as shown. Then we have the front side 2 feet longer than the others, and the angles the same. Three sides of any figure composed of more than four sides can be produced in the same general manner. However, the ratio between the mean part and the extremes will be different. Thus, in a figure of seven sides the mean part will be one-fourth of the extremes. Whatever the mean part is, the

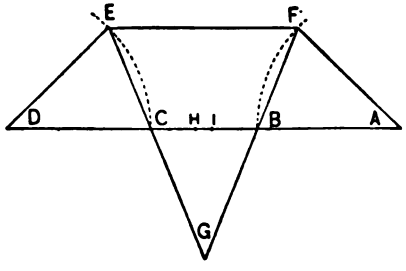


FIG. 83

sides will be equal and the angles at E and F will be the same.

FIG. 84

OCTAGON TOWERS AND SPIRES

Now that we know how to lay out the base of an octagon and how to lay off a part of the figure for a bay window or other similar work, it will be in order to see how the framing is done for an

octagonal tower, spire, or other similar structure. Suppose we have a tower to erect which is partly over another roof, as shown at Fig. 84, where the intersections occur. It will be seen that the tower intersects the hip roof, as A,B,C,D,E,F,G.

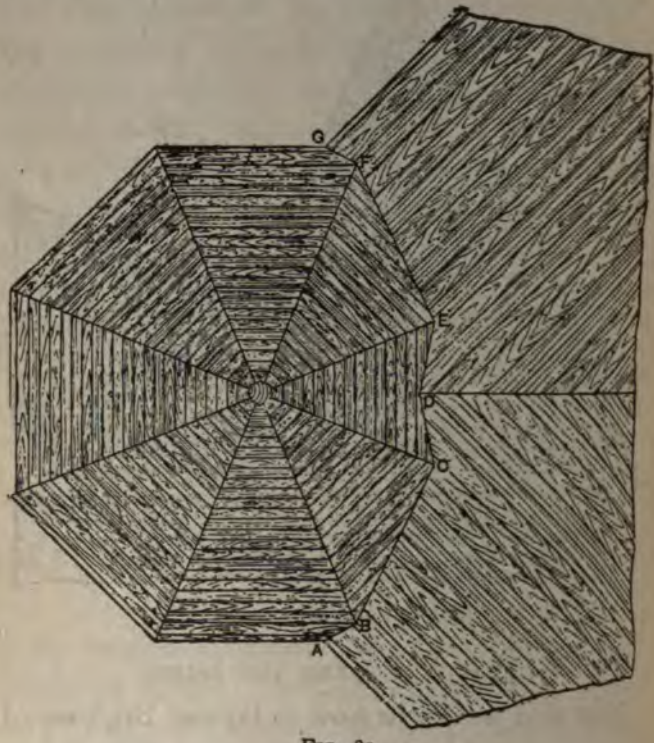


FIG. 85

Before the intersections shown by Figs. 84 and 85, and the timbers shown by Figs. 87, 88, and 89

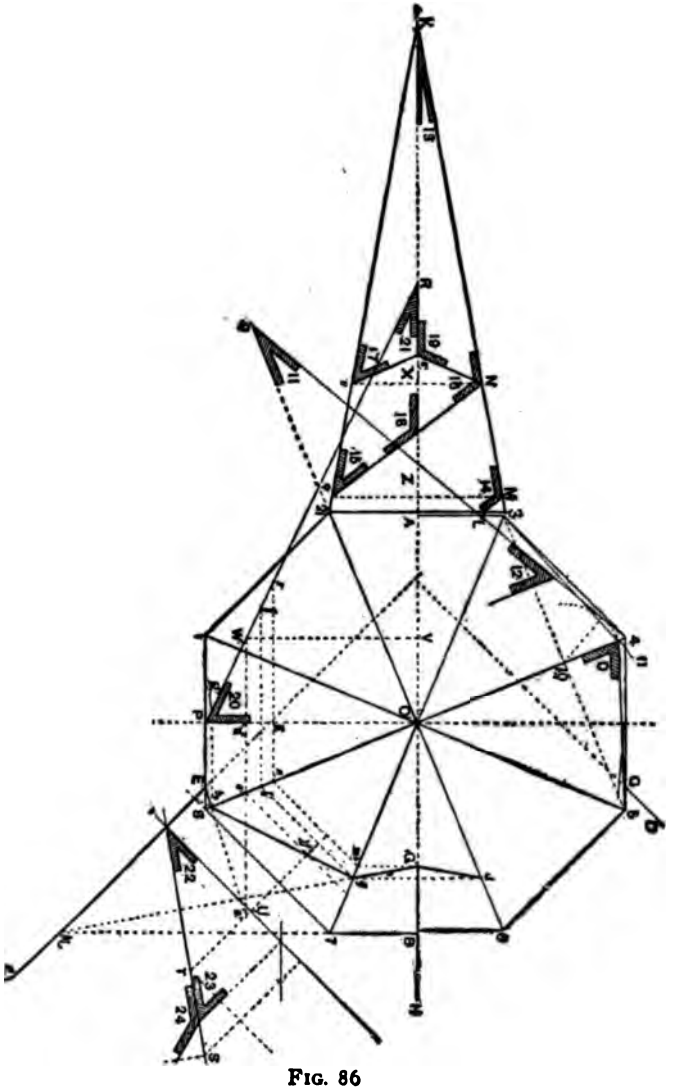


FIG. 86

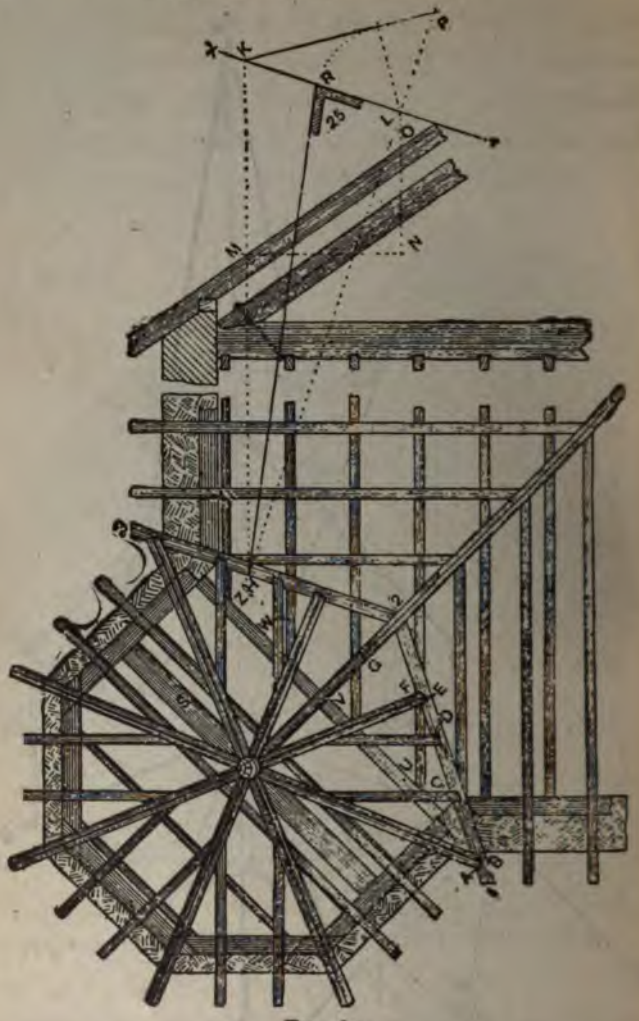


FIG. 87

can be properly set out, it will be necessary to

obtain the intersections of the boarded surfaces geometrically. The method of doing this is shown by Fig. 86, and is as follows: Set out the half octagon A2187B, which is the line of board-

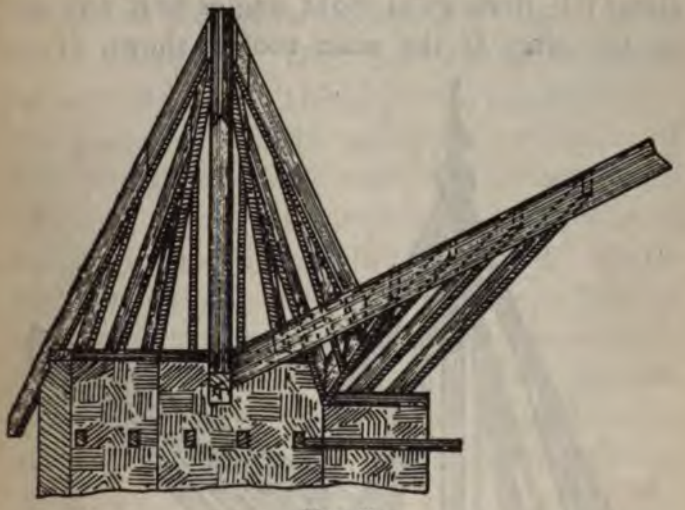


FIG. 88

ing. The other half, A3456B, it will be noticed, is a little less, this being the line of rafters. To avoid confusing the diagrams with a number of lines, several of them have been omitted; it would of course form a smaller parallel octagon to those shown. Next set out line CD, which is the line of feet of rafters, and EF, which is the line of face of the fascia board of the main roof, also the line of the main hips, as shown at GH.

can be used to show the correct shape of the surfaces which intersect the roof. From *b* project up to meet the line PR in *b'*; make AZ equal to P*b'*; then through Z draw line *g*ZM parallel to A3; next make 3L equal to E8. Then 2LMK is the true shape of the side IE*b*O. From *g* draw a line parallel to 7-8, meeting 8-o in K; then from the point K draw a line parallel to 1-8, and continue it to meet PR, and meeting *b*. Now measure off on the line AE a distance AX equal to P*l*. Through X draw a parallel to 2-3, meeting 3K in point N. Join N*q*; then N*qk* is the true shape of the surface *gbo*. From G draw G*mns* parallel to B78P. From *s* project up to meet PR in *r*. Make A*u* equal to *r*P. Join N*u* and *uv*; then N*uv*K is the true development of the surface JG*g*O.

The method of obtaining the bevels of the several parts may now be described, the means of obtaining the backing of the hips being first shown. At right angles to 0-4 set 0-9, and make it equal to the height; join 4-9, which gives the true rake of the hips. At 11 is shown the bevel for the vertical cut of the top, and at 12 that for the foot. As will be seen, one edge of this bevel is adjacent to the pitch line; the other, being horizontal, is drawn parallel to 0-4. For the

backing of the hips, join 3-5, and from where this line meets 0-4 in point 10, draw an arc tangent to the pitch line 4-9. From where the arc meets 4-10 in point 11, join to 5 and 3 as shown; then D is the bevel required.

The bevel for where the hips meet each other is shown at 13. Reference to Fig. 87 will show where this bevel will be required, and also that the upper part of the mast or central post is octagonal. This allows the upper cuts of the hips to be made square through their thickness, and therefore no bevel is required. The development of the intersection shown at 3MNK*vg*2 gives us the bevels for the feet of the hips and rafters A, B, C, D, E, F, and G, Fig. 87. The bevels 14, 15, 16, and 17, Fig. 86, are the feet of the hips A, B, E, and F, respectively, Fig. 87. These bevels are for application after the hips have been backed. The bevels to apply to the backs of the jacks at C and D, Fig. 87, are shown at 18, Fig. 86.

Whilst the bevel for the foot of G, Fig. 87, is shown at 19, Fig. 86, it will be noticed that the valley rafters shown by 1, 2, 3, Fig. 87, have their upper edges in the same plane as the main roof; therefore, it will be necessary to obtain a bevel for the preparation of these edges. The geo-

metrical construction for this is as follows: From any point in the plan of the valley, as H, Fig. 87, draw the horizontal lines HK and HL at right angles to 2-3; then at any point on HL draw XY at right angles to it, and cutting the line HK in K. From where HK cuts the pitch of the roof, as shown at M, draw MN at right angles to HK. Then from L drop a perpendicular to MN as shown. Next project LP at right angles to XY, and make it equal in length to NO. Now join KP; then with L as a center, draw an arc tangent to KP, meeting XY in R. Join RH, which gives the bevel required as shown at 25.

The bevels for the jack are shown at 20 and 21, Fig. 86, whilst the bevel at 13 is for application to the tops of the jack rafter, or these bevels may be obtained by the steel square as shown in previous examples. The methods for obtaining the bevel for the jack rafters for the main roof may be obtained by the square, as shown by 22, 23, and 24, Fig. 86, respectively. The hip of the main roof, as will be noticed, requires supporting at the lower end. This is done by placing a dragon beam across the octagonal space, as shown at S and S, Figs. 87 and 88. Then the end of the hip should be notched, as shown at Fig. 90. The ceiling joists in the octagonal space

are fastened into the wall as shown on plan, Figs. 87 and 88. Of course, as is usual, the ceil-

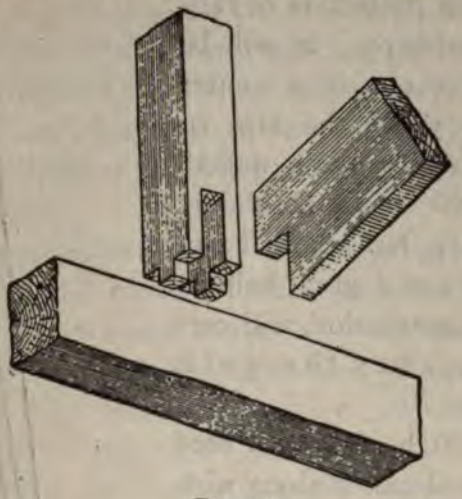


Fig. 90

ing joists should be on the same plane as the ceiling joists in the main building; the ends of four of these, U, V, W, and Z, cannot be carried to any wall, therefore a trimmer is provided of stouter scantling to carry these ends, as shown in the plan and section, Figs. 87 and 88. The boarding is clearly shown in Figs. 84 and 85, and therefore does not require further description. There are other little points which are fully shown in the illustrations, but it has not been thought necessary to enlarge upon them here.

At Figs. 88 and 89 the manner of construction is shown, including projection of rafters over eaves. It will be noticed there is a center post to which the hips or corner rafters are nailed. This post is not absolutely necessary, but when it can be used it is a great help to rapid construction, and certainly makes the work stronger.

The pitch of a tower roof may be obtained along with all the bevel lines by a proper use of the square, as shown in Fig. 91, which illustrates some unusual pitches. It is evident that if the run of one foot is 12 inches the run of two feet must be double that or 24 inches. Therefore the rise must be that proportion of 24 inches. The first inch in rise is $\frac{1}{24}$, the second $\frac{1}{12}$, and the third

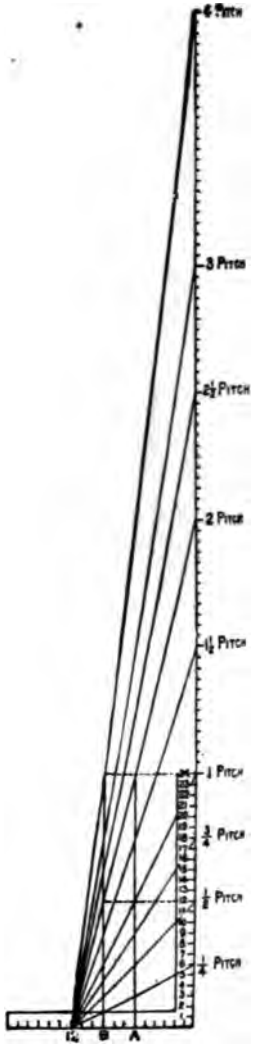


FIG. 91

⅛, the fourth ⅙, etc. The twenty-fourth inch rise being equal, the span is therefore 1 pitch. As the rise continues above this point, it is simply a repetition of the above with a 1 prefixed, thus: The twenty-fifth inch rise being 1¼ pitch, etc.; but we are now beyond the limits of the full scale as applied to the square, so we must reduce the scale.

By letting the vertical line at A represent the blade we will have reduced the scale one-half. The pitches would center at 6 on the tongue instead of 12, as in the full scale. We must now use the half inches above 12 on the blade for each inch in rise till we reach the twenty-fourth inch which will be equal to 2 pitches or 48-inch rise to the foot.

For steeper pitches it is necessary to again change the scale. If we let the blade rest at B the pitches will center at 3 on the tongue (making the scale ¼ size), and by letting the ¼ inches above 12 on the blade represent the full inches in rise will give the cuts, etc., from the forty-eighth inch rise to the ninety-sixth inch rise to the foot, or 4 pitches.

One of the methods of laying off the lines for an octagonal roof having curved rafters is given at Fig. 92, where a method of obtaining the

curves is given. The plan is shown by the octagonal figure, and we will suppose it to be 20 feet

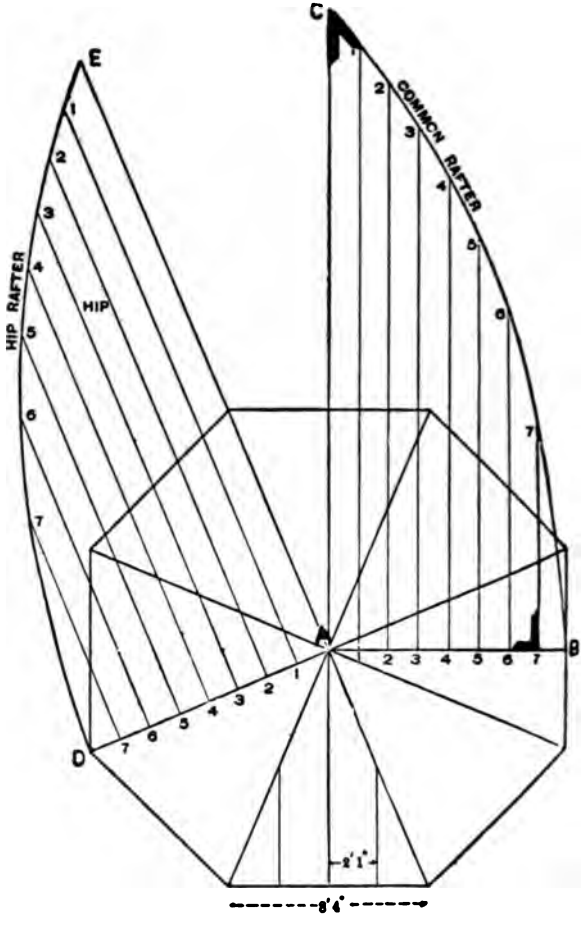


FIG. 92

in diameter and the rise of roof 25 feet. AB is

the run of the common rafter and AC its rise. Divide AB into as many parts as may be necessary and square up from each of these points parallel to AC, and cutting the curved line CB, which in this case is struck with a sweep of 38 feet. Now divide the run of the rafter AD into the same number of equal parts as the run of the common rafter AB. Erect perpendiculars from each of these points at right angles to AD and set off from A to E the same distance as that from A to C on the common rafter. Next set off 11, 22, 33, etc., on the hip to correspond with 11, 22, 33, etc., on the common rafter, and connect these points. The result is the shape of the hip rafter. As for the jack rafters, their lengths depend on the number necessary. If one is sufficient, its length would be one-half that of the common rafter taken on the working line, and by making the cut for the upper end through this point, as shown at 4 where we have the proper length of the jack. The plumb and vertical cuts of the jacks are the same as those on the common rafter. The figures on the steel square which give the cuts for an octagon are 7 inches and 17 inches; the 7-inch side giving the cuts. The figures on the square which will give the cuts for common rafter in this case are 5

inches on the tongue and 12½ inches on the blade; the latter giving the upper cut and the tongue the lower cut. The figures giving the cuts for the hip rafter in this case are 5 and 5½ inches on the tongue and 12½ inches on the blade; the latter giving the plumb cut. This will be readily understood for the reason that the run of a hip rafter on an octagon is one-twelfth greater than the run of the common rafter. One method of obtaining cuts of the jack rafters is shown on the lines AB and BC. It will be seen that it will work in any case, no matter what may be the pitch of the roof or the shape of the rafter. Obtain the plumb cut of the upper end of the rafter BC, which is the same as that of the common rafter. Then square across from A to B on the upper edge. Now, as 7 inches and 17 inches on the square will give the cuts of the jacks if they are to have no rise at all, the same will work when they have a rise. Take seventeen-sevenths of the thickness of the stuff which is being worked and set it off square from the line BC to the outer edge, as CD. Then a line from A to C is the bevel of the jacks. All these cuts and lengths may be obtained by using the square, as has been shown in previous examples.

Another method of obtaining the curves for hip and jack rafters is shown at Figs. 93 and 94. The lengths and bevels will, of course, be the same as though they were to be straight, and lay them out in that way on boards wide enough to make the curve. It is best to have them planned and jointed on the back, then strike the curve of the common rafter. It may be struck with a trammel from one center, as in the sketch, or of any shape that may suit the fancy or conditions of the case. Next, divide the length of the rafter on the jointed edge of the pattern into any number of equal parts and draw the lines, as 1, 2, 3, etc., in the sketch, Fig. 94, on the same bevel as the plumb cut. Then proceed in the same

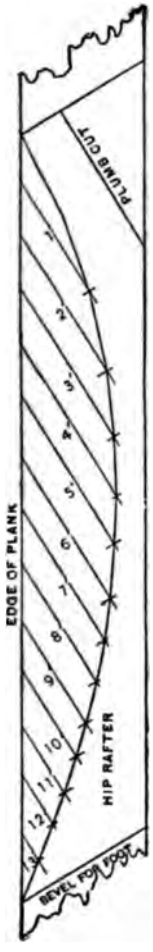


FIG. 93

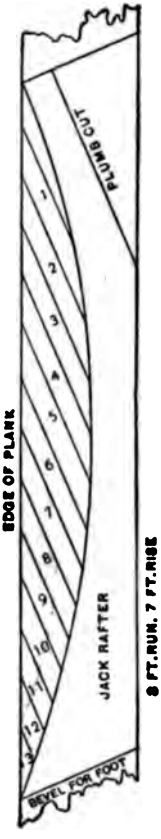


FIG. 94

manner with the board for the hip rafter, being careful to divide it into the same number o

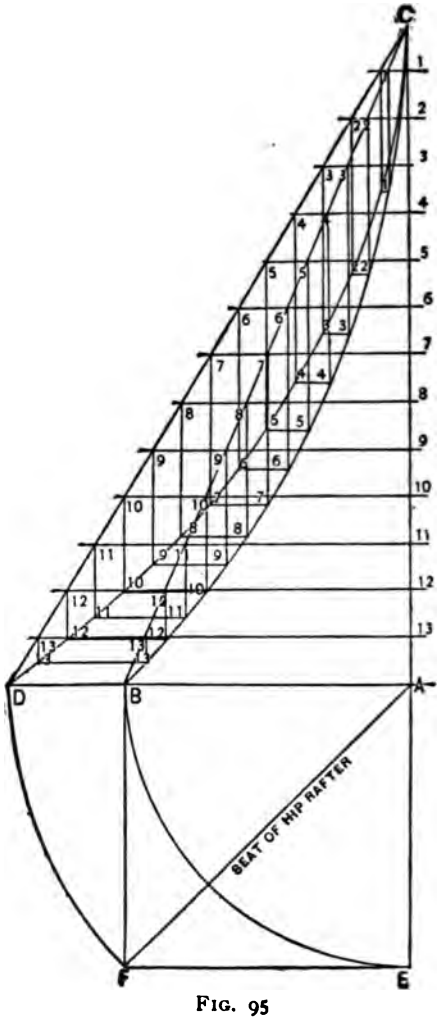


FIG. 95

equal parts, and draw the lines parallel with its plumb cuts. It will be found convenient to number the lines on the patterns the same as shown in the sketch; then, with the dividers or rule, lay off 1′ on the hip equal to 1 on the jack, 2′=2, 3′=3, etc. Then spring a light line or edging and draw through the points thus obtained. If the work is done correctly the two sides of the roof will meet exactly on that line. It will be readily seen that it makes no difference whether the hip is to be set on a square, hexagon, octagon, or at the angle of any other regular figure, providing run and length are first properly set off. Another method, which may be termed a "geometrical method," is shown at Fig. 95, and to those who have any knowledge of geometry further explanation will be unnecessary. It is given here merely as a comparison and may, perhaps, be found useful to a few readers.

The plan and elevation shown at Fig. 96 is almost self-explanatory. It simply shows the lengths and bevels of hips and jacks. The cuts in both hips and jacks are the same as would be for common rafters, except that instead of a square cut across the back of the rafter it must be at a diagonal to fit against the side of the hip, as shown by the dotted lines at A and B.

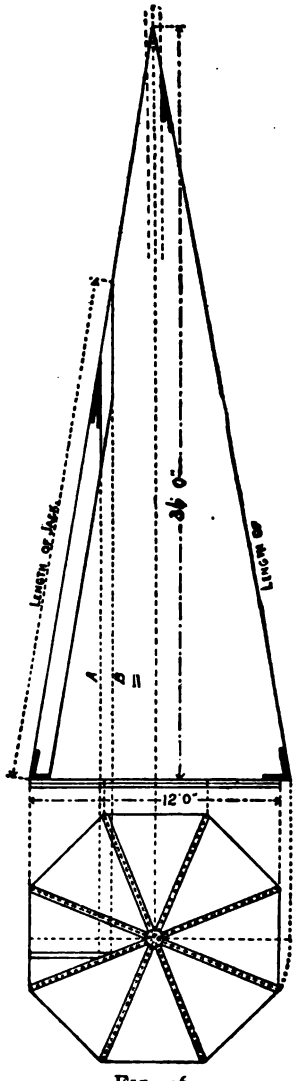


FIG. 96

These lines are always vertical and the same distance apart regardless of the pitch given. A diagonal line from A to B across the back of the jack determines the angle.

Fig. 97 illustrates this point. If there was not pitch at all then 5 and 12 would give the cut. These figures also give the starting points of lines A and B, which, since the rafters are of the same thickness, will remain at right angles the same distance apart. Thus, if the rafter be 2 inches thick, the lines A and B will be 4¾ inches apart.

The jack cut may also be found as follows: Take 5 on the tongue and the length of the common rafter for one foot run on the blade, the blade giving the cut.

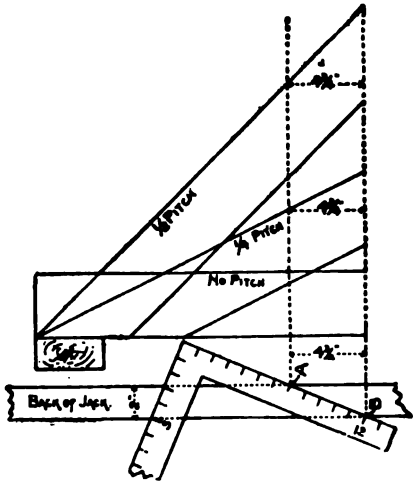


FIG. 97

Fig. 98 is a modified diagram of Fig. 96.

OCTAGON DORMERS

I have thought fit to present to my readers a few illustrations showing how an octagonal dormer is treated in the framing of a first-class roof by architects of note. But little more is necessary than the plans, sections, and elevations showing the mode of construction to enable the reader to understand the whole arrangement.

Fig. 99 shows, in a conventional way, how the timbers are arranged and framed in order to make the dormer bay strong and effective. The

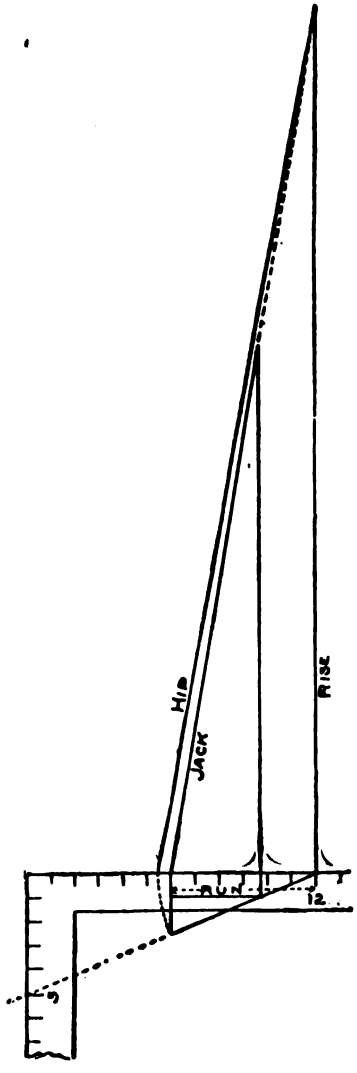


FIG. 98

sidelights in a dormer of this kind are generally fixtures, while the front sashes may be hinged and open in two leaves, or they may be so constructed as to hang with cords and weights.

Fig. 100 shows a front elevation of the framework with sashes in place; and fall-back gable of roof, rafters, and all studding are seen in position. Fig. 101 shows a plan of the whole construction, including top of brick wall, plate, and gutter. This figure requires no further explanation.

Figs. 102 and 103 show side elevations of portions of roof and dormer.

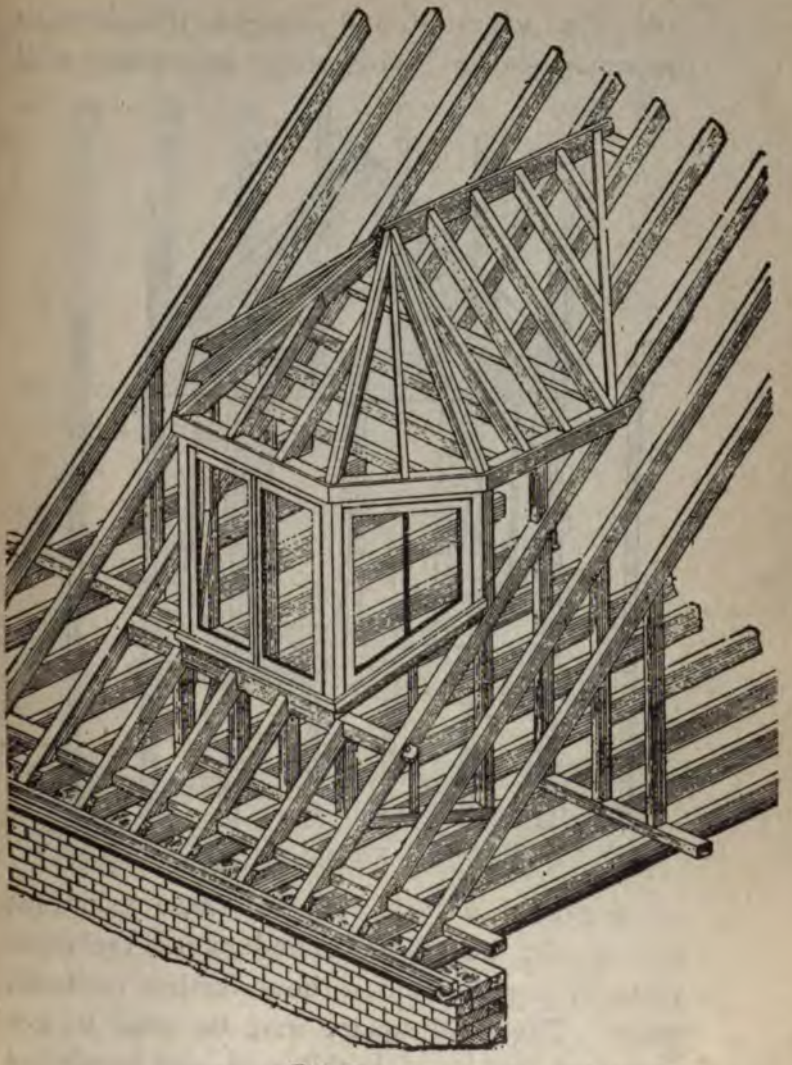


FIG. 99

At Fig. 104 a ground plan of the dormer proper is shown giving shape of corner and

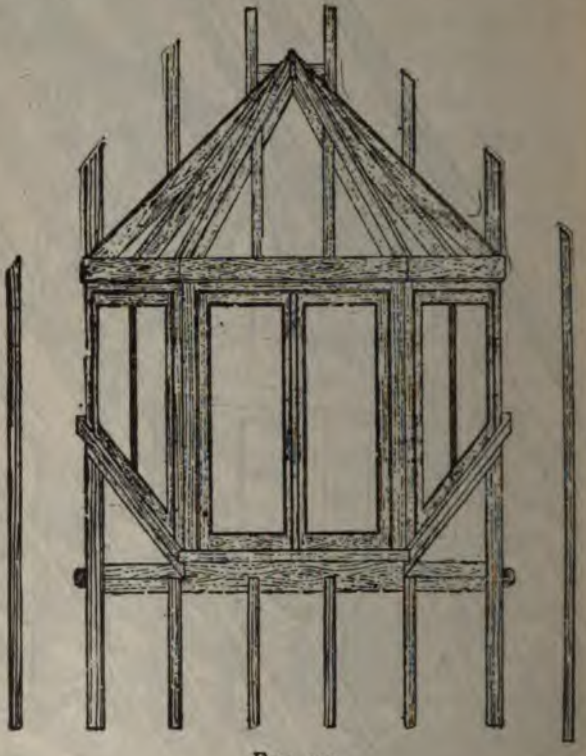


FIG. 100

angle posts. A little study of these examples will enable the reader to understand the principle of construction without further explanations. The steel square may be used to get every cut and bevel in this roof, also bevels for

he window sills, as shown in Fig. 105, and which s explained as follows: Take the height of

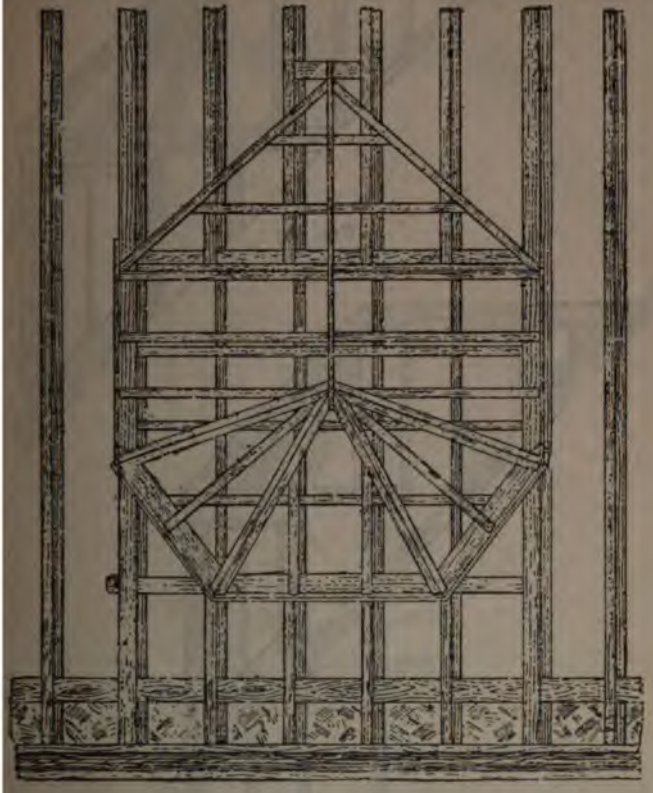


FIG. 101

ise A to A′ and set up from B to C each way. ntersect the two lines at D, one at an arc struck rom O as a center, and the other from E. The ne from O to D will be the bevel for face of

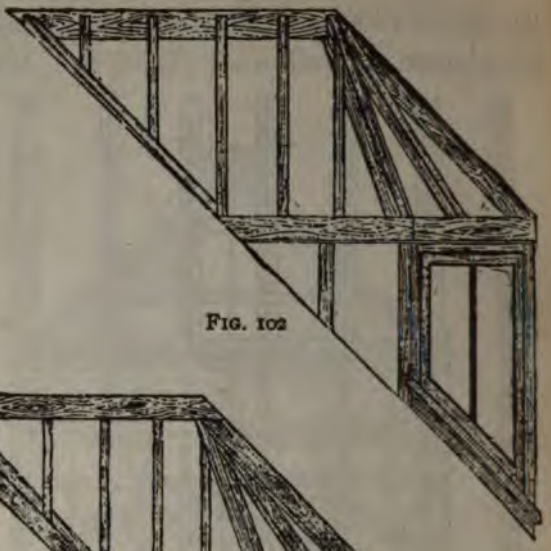


FIG. 102

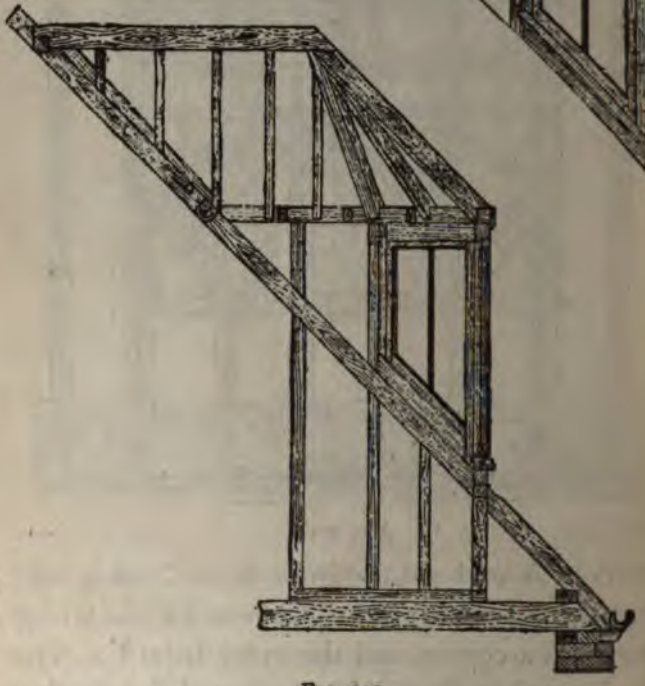


FIG. 103

sill. To obtain the down cuts, drop a line from the point of overhang of sill to the line of inter-

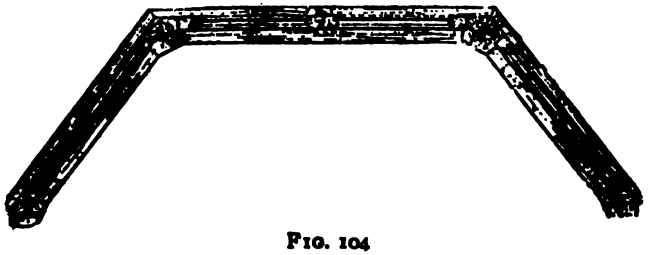


FIG. 104

section of the angle of the bay window. Set off the thickness of sill parallel to face of window.

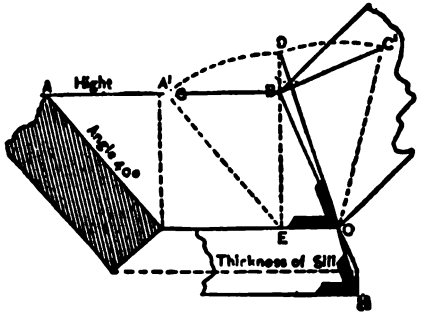


FIG. 105

Square up from where the point of overhang cuts the line of intersection of angle to the thickness of sill, and draw a line from H to O, which will be the bevel or down cut. This, of course, gives the bevels for all sides of the sills. At Fig. 106 show an octagon tower in place, or rather the

method of framing same on a balloon building over a veranda. Sizes of timbers are shown. The example may be of use.

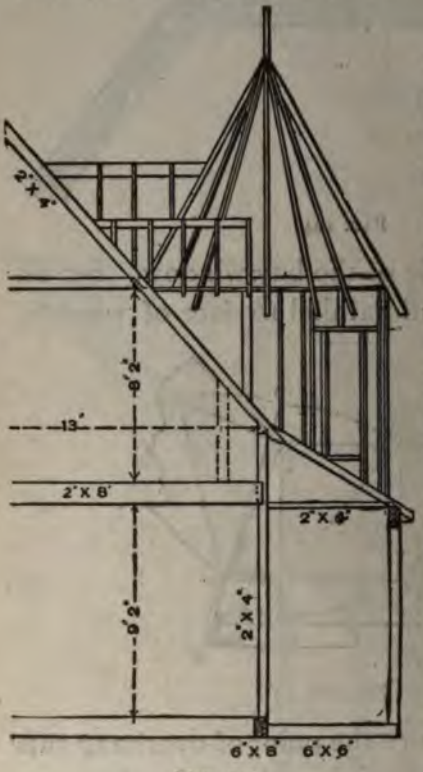
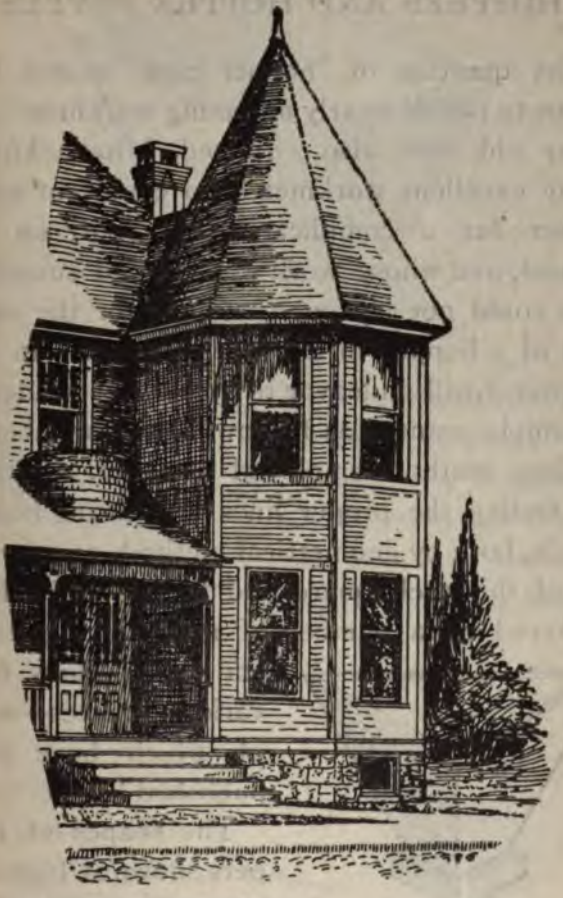


FIG. 106

Fig. 107 shows a plain octagonal tower finished. This is in connection with a two-storied frame house that is sided outside. A portion of veranda and front entrance is shown. The whole is made as plain and economical as possible. While these last two figures have no direct connection with the steel square, it is thought they may be useful as showing the work when finished.



FIG, 107

HOPPERS AND HOPPER BEVELS

The question of "hopper cuts" is one that seems to puzzle nearly all young workmen—and many old ones also. Indeed, I have known many excellent workmen who could cut every timber for a complicated hip roof, on the ground, and whose work was beyond suspicion, who could not lay out the lines for the miter cuts of a hopper in a proper manner. In this chapter I will endeavor to give to the reader, in as simple manner as I know how, a number of the best methods employed by expert workmen for finding the proper lines for cutting hopper bevels, both by geometrical methods and by the use of the steel square, and to this end I have gathered up a number of methods, diagrams, and explanations from various sources—many of which have been published before.

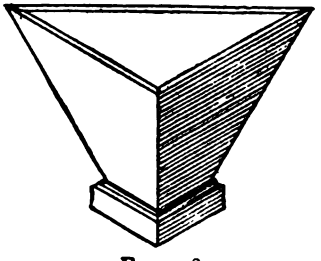


FIG. 108

The shapes of hoppers shown at Figs. 108. 109, and 110 are triangular, square, and hexagonal respectively, while Fig. 111 shows a cover

or box lid, which requires a little special treatment.

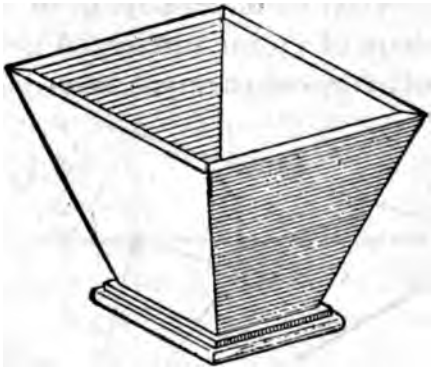


FIG. 109

I will treat all these figures in a geometrical way, so that the reader may know the "reason why" it is necessary for certain cuts to have certain lines that are at va riance with certain lines in apparently similar cases. The geometrical problems involved in these cases consist (1) in finding the dihedral angle be-

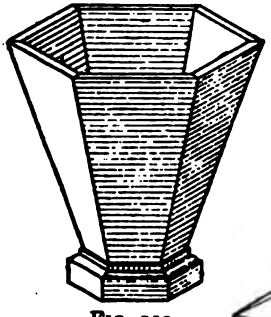


FIG. 110

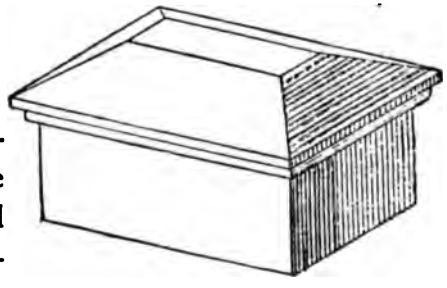


FIG. 111

tween two planes; (2) in bisecting this angle, which gives the bevel; (3) in developing or obtaining the true shape of a plane surface. A geometrical problem of a very ordinary type, involving the first

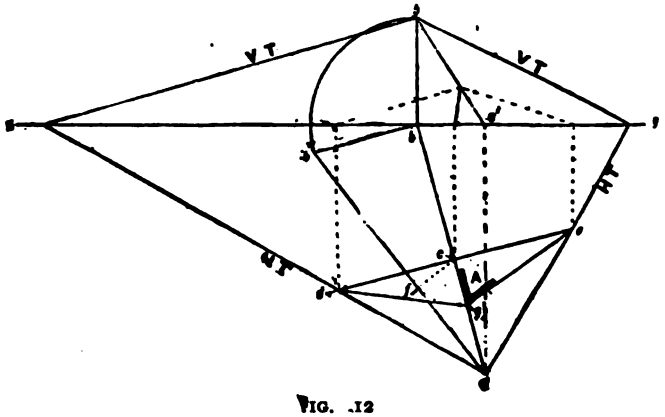


FIG. 112

two of this character, is shown by Fig. 112, where two planes are indicated by their horizontal and vertical traces. The solution is as follows: First find the plane and elevation of the intersection *ab*AB. Next obtain the true length of the intersection by rebating it into the horizontal plane as shown by *a*B. Through any point *c* on *a* draw *dc* at right angles to *ab*. Then from point *c*, draw *cf* at right angles to *a*B. Then with *c* as center and *f* as radius cut *ab* in *g*. Join *eg* and *dg*; then *dge* is the dihedral angle between the two planes. Then, given two pieces of material of equal thick-

is meeting, and it is desired to miter-joint
:m, the angle for this would obviously be half
: dihedral angle, as A.

Let this geometrical reasoning be applied to
: case illustrated by Fig. 113, which, as will be
:n, is a direct application of the problem just
scribed, *ab* indicating the plane and *a'b* the
vation of the line of intersection of the two
jacent plane surfaces. Draw *b''* at right angles
ab, and make it equal to *hb'*; then joining *a* to
gives the line of intersection rebated into a
rizontal plane. Then proceeding with the
istruction as explained at Fig. 112 (it will be

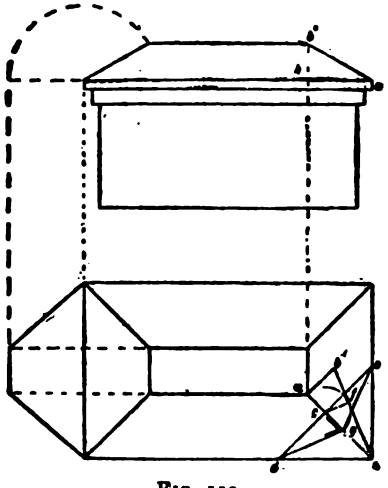


FIG. 113

:n that Fig. 113 is similarly lettered), the angle

between the two surfaces of the lid is obtained. Half this angle gives the bevel required for the mitered joint as there shown.

In the cases considered the working has been

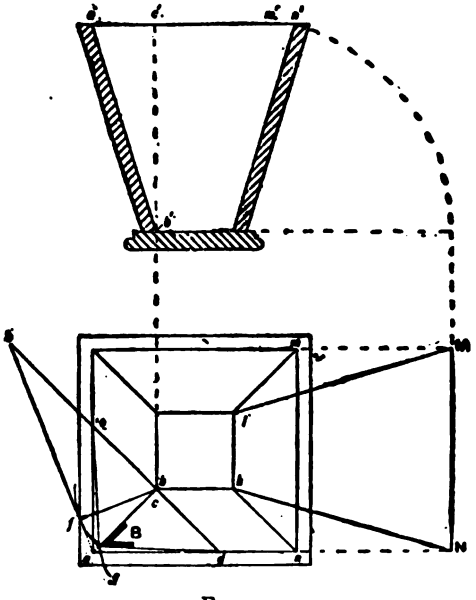


FIG. 114

in front of the vertical plane and on the horizontal plane; that is, in the first dihedral angle of the co-ordinate planes. This has been the most convenient method, because the surfaces slope up and away from the observer; whereas in the cases shown by Figs. 114 to 116 the surfaces slope upward and toward him, and there-

fore, for a person who has the necessary knowledge of geometry, the simplest method will be to work under the horizontal plane, but in front of the vertical, that is in the fourth dihedral angle of the co-ordinate planes. Taking the case of Fig. 114, *ab* is the plan of the intersection of the two surfaces. At right angles to this, set up the line *b*B, making it equal to BC. Join *a*B; then this line is the true length of the intersection constructed upward into the horizontal plane. Then through *c* draw *de* at right angles to *ab*—it should be noticed here that half the line *de* coincides with B, the intersecting surfaces being equally inclined. Then from *b* draw *bf* at right angles to *a*B. Next, with *c* as a center and *cf* as radius, describe the arc cutting *ab* in *g*. Then joining *dg* and *eg* gives the bevel required, as shown at B. By imagining the object at Fig. 114 turned upside down, exactly the same kind of working as that just described would apply; but perhaps the problem will be simplified by imagining that the work is in the first dihedral angle of the co-ordinate planes. To many who understand geometry this method of working this problem will commend itself as being simplest to imagine, although giving the same results. In Fig. 115 precisely the same reference

letters have been adopted, and it will be seen that the same problems and principles are involved.

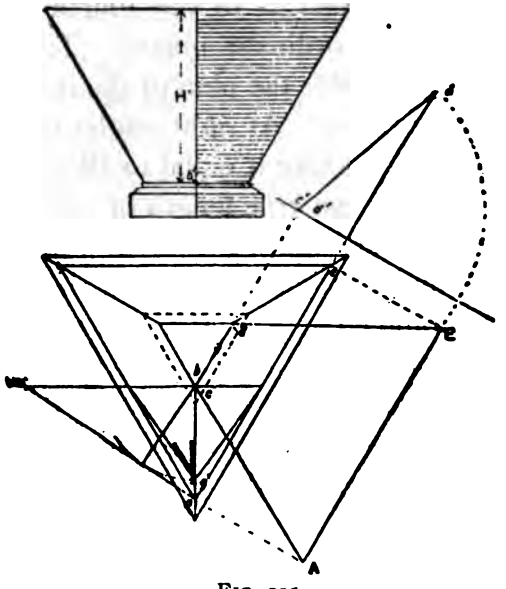


FIG. 115

The geometrical formula for finding the true shape of development of the sides is: Given the plane and inclination of a plane surface, determine its true shape. A problem of this class is shown at Fig. 117. Let *abcde* be the plan of the given figure, its side *ab* being the horizontal plane; through *ab* draw a horizontal line, at right angles to which draw *xy* as shown; next

set out the angle of inclination of the figure as shown by the line VT, which may be considered

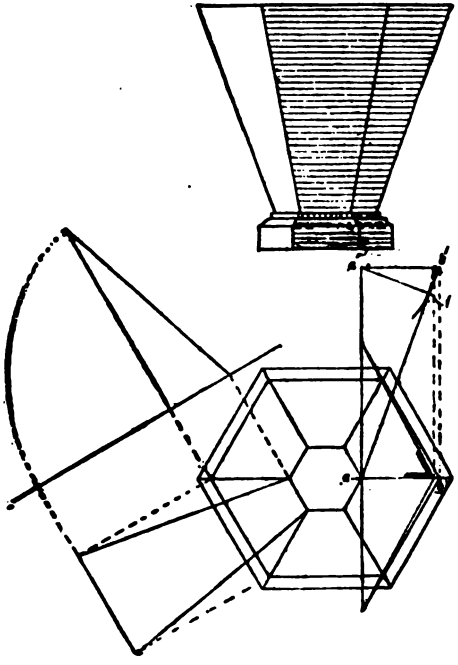


FIG. 116

as the vertical line of a singly oblique plane. From the plan set up projectors to this plane, then rebate back the figure into the horizontal plane by drawing the arc projections to *xy*; and from these, projecting at right angles to *xy*, and from *cd* and *e* parallel to *xy*, gives the points CD

and E. Joining *a* to E, E to D, and D to C, and C*b* gives the true shape required.

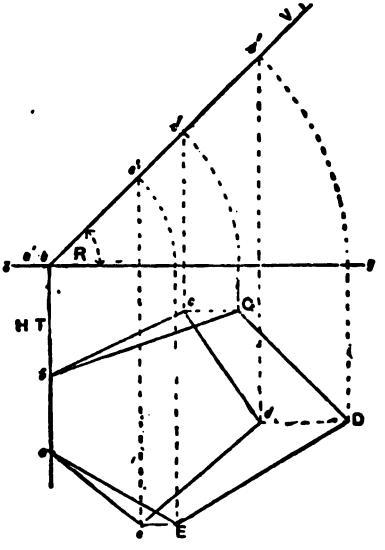


FIG. 117

If the working of this problem has been carefully followed and mastered, its direct application to cases shown at Figs. 113, 114, 115, and 116 will be readily understood.

The foregoing is meant primarily for geometricians, and secondarily for those who wish to know the "reasons why" of hopper bevels.

Having shown this much, simply to satisfy the "learned" in "theoretical" carpentry, I will now proceed to show how all the lines and cuts may

obtained for this work by aid of the square ne and in a speedier and simpler manner. .et us suppose Fig. to represent a sec- ı through a hopper; n take a board 12 ıes wide, joint one e and draw a line :he side elevation according to the refine- ıts. From this proceed to make a draft with the square 1 inch to a foot. Take 12 inches on the blade, hold 12 at A, and by it find how many inches rise the given inclination is to a foot. Draw a line by the tongue, as shown by BV, Fig. 119. At B draw square with AC, and again square on line AB through C, as shown by CL. From VB erect a perpendicular also to C, cutting VB in the point E. By these several opera- s we have a complete draft by which to solve problem. AB is the given slant, and has 9

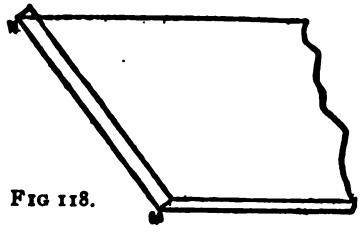


FIG 118.

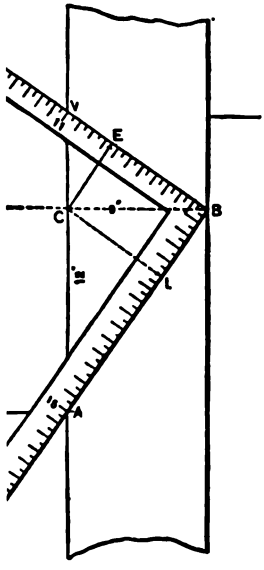


FIG. 119

inches rise to a foot. AC is 12 inches, and CB is 9 inches. The length of AB, as indicated by the figures on the square, is 15 inches. Fifteen inches, therefore, is the width of the board required to cut the hopper.

Use the foot draft of the hopper as follows:

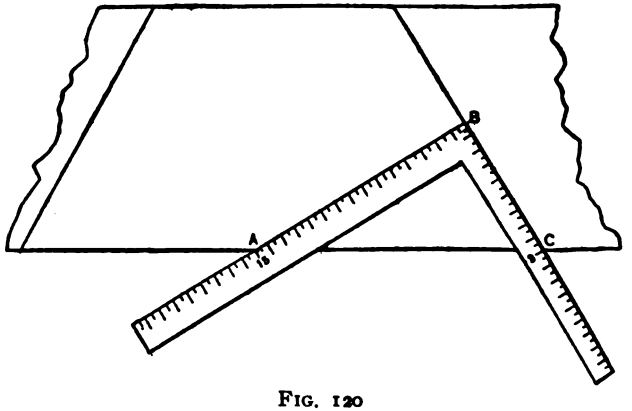


FIG. 120

Take on the blade AB, and on the tongue CB, and apply the square to the board as shown in Fig. 120. Mark on the tongue, which will give the down-cut bevel.

For a butt joint take EC on the tongue and CA on the blade and apply it as shown in Fig. 121. Mark on the square edge of the board EC.

The above principles will give the manner of backing a hip rafter. Suppose that AC, Fig. 119, were the seat of the hip rafter, and AB the

length of the hip, by taking CL on the tongue and CB on the blade, marking on CL and setting

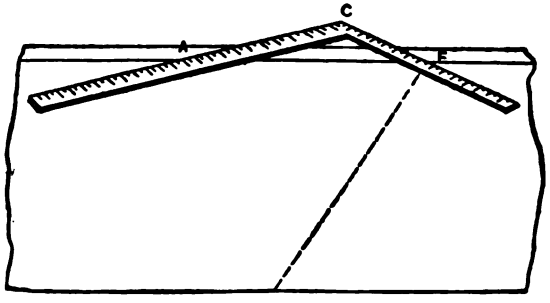


FIG. 121

the bevel by that line, the exact backing of the hip will be obtained. The handle of the bevel is to be square across the hip rafter, as shown at CL in Fig. 119.

A very good way, and one I have found to work out correct, and which I take from "Carpentry and Building," for obtaining the butt joints for hoppers, is as follows: Draw a line CD, Fig. 122, at the same angle with the straig h edge of the board AB as the sides of

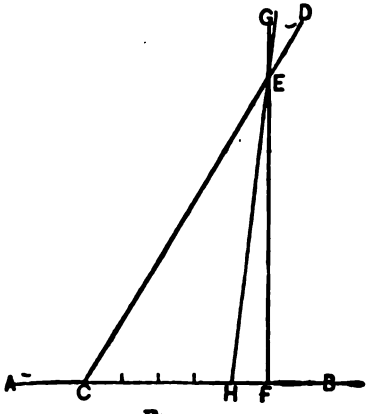


FIG. 122

the hopper are to stand. Cut this line at any point, E, with a line, FG, drawn at right angles with AB. Divide CF into five equal parts, and through the fourth point thus established draw a line as shown from H, cutting E. Then HE will be the bevel of the butt joint. This rule will work no matter what the flare of the side or width of boards used, providing always the hopper is square-cornered.

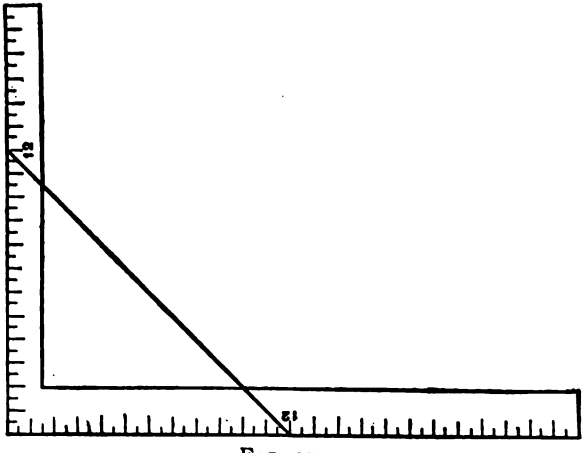


FIG. 123

A handy rule is given as follows: Let Fig. 123 represent the slant of the hopper as shown by the line running from 12 to 12 on the square. Figs. 124, 125, and 126 show the applications. Fig. 123 represents the square with a line drawn from 12 to 12; this line shows the flare of the

)per. The distance from 12 to 12 on the diag-
ıl line is 17 inches nearly, as I have shown

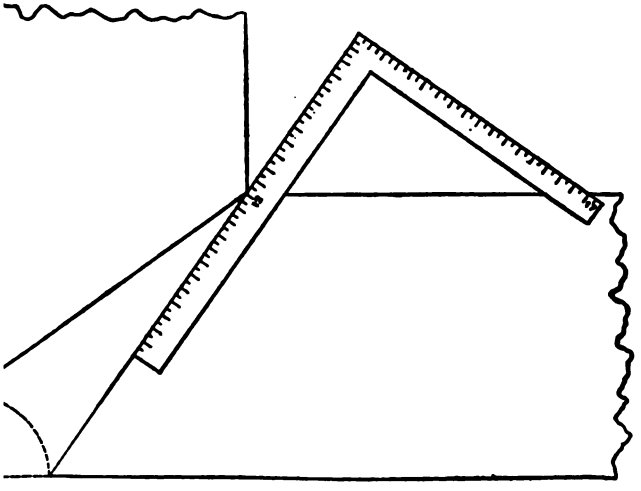


FIG. 124

viously. The angle of the miter on the hori

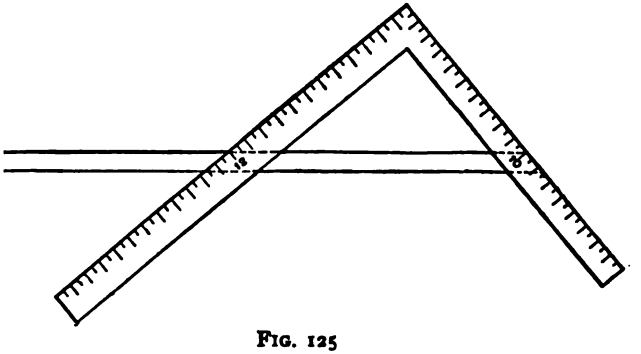


FIG. 125

tal is 45° or a true miter. The base line

from the corner of the square to 12 is 12 inches, the pitch line is 5 inches longer than the base line (the difference between 17 and 12 inches). Add 5 inches, the excess of the pitch from the base line, and we have 12 and 17 inches of bevel and miter. The application of this is shown in Figs. 124 and 125. For a butt-joint the sides slant two ways on each angle. The angle on the horizontal is a right angle. The excess of the pitch from the base line on the one side is 5 inches, and on two sides 10 inches, making an angle or

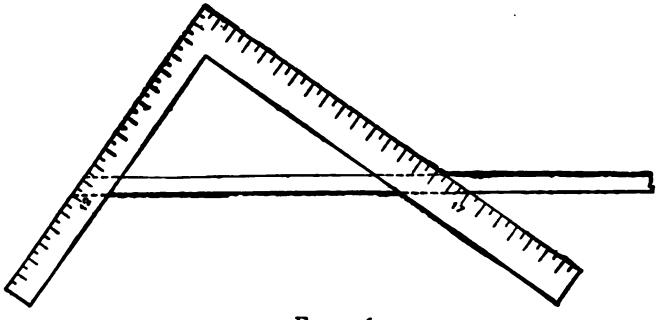


FIG. 126

joint 12 and 10, as shown in Fig. 126. The latter figure shows the application of the rule named; all the stuff being square-edged. This method when thoroughly understood is very simple and effective.

Another method, somewhat similar to the one

already shown, is given herewith. To obtain the bevels of a hopper either by the square or lines, the rise to the foot of the sides being given, first ascertain the hypothenuse from 12, taken on the blade of the square, to the rise to the foot, taken on the tongue. Divide the square of 12 by the rise to the foot. Apply the square to a straight-edge, taking the hypothenuse on the blade and 12 on the tongue. This will denote the surface bevel. Again, apply the square to the straight-edge, taking the hypothenuse on the blade and the rise to the foot on the tongue. This will denote the bevel of the miter-joint, so called. For a butt-joint, take on the blade the quotient arising from the division of the square of 12 by the rise to the foot, and on the tongue take the hypothenuse. Then the blade will denote the bevel required.

Another method on the same diagram is as follows: Apply the square to a straight-edge, taking 12 on the blade, the rise to the foot on the tongue, and mark by the blade to obtain AD of Fig. 127, which represents the inclination of the sides. At random make BD perpendicular to ABC, which represents the straight-edge, taking AD on the blade and AB on the tongue. This will give the surface bevel. Again, apply

the square, taking CD on the blade and BC on the tongue, which will denote the bevel for the

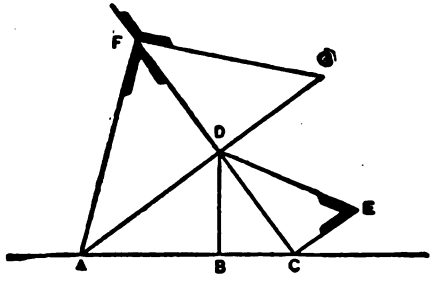


FIG. 127

miter-joints. For butt-joints apply AB taken on the blade and CD taken on the tongue. The blade will denote the bevel required. The same results may be obtained by geometrical construction, as follows: Referring to Fig. 127, make DF equal to AB, and draw AF; make DG equal to CD and draw FG; make CE perpendicular to CD and equal to BC and draw DE. The designated acute angles at F will be the angle of the surface bevel. The designated obtuse angle at F will be the bevel for the butt-joint. The angle at E is the bevel for the miter-joint.

The foregoing may be applied to roofs of one pitch over rectangular bases. Fig. 128 represents a section of cornice. That which relates to the surface bevel is applicable to the surface bevel of the boarding, the outward bevel of pur-

lins which come in contact with each other or with hip rafters, the surface bevel of the planceer in a cornice similar to the diagram, and the edge bevel of a fascia. That concerning miter-joints is applicable to the edge bevel of the boarding, the inward or down bevel of purlins, and the surface bevel of the fascia. Applying the square to a straight-edge, according to the directions given in the first and second methods above presented for obtaining the surface bevel, and marking by the blade, we obtain the edge bevel of jack rafters. In Fig. 127, FAD denotes the edge bevel of jack rafters. In order to properly get the crown molding for a cornice similar to the drawing, lay off on the edge of a miter-box the surface bevel of the board, and on the sides the edge bevel.

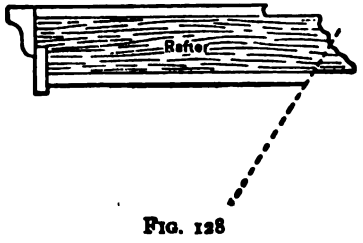


FIG. 128

Hopper cuts to a large extent are similar to the cuts required for fitting boards in or over a valley or hip roof; consequently the figures on the square that give the cuts for the roof boards must give the cut for a hopper of the same pitch.

Fig. 129 shows a hopper in different views, as follows: Beginning at the top is the top view of

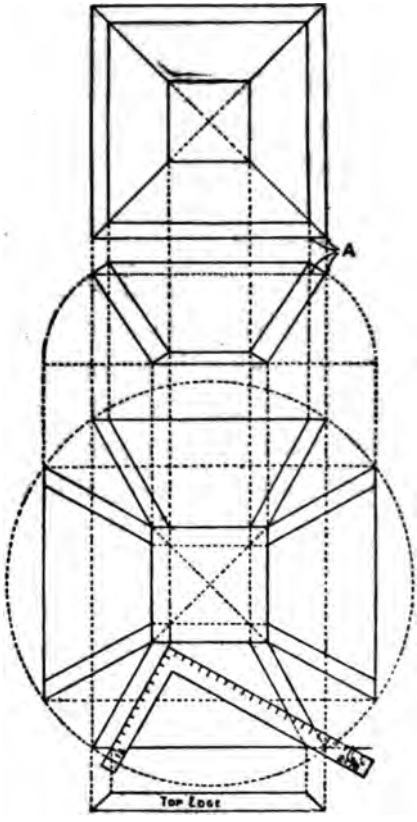


FIG. 129

the hopper. As far as this part is concerned all hoppers look alike, as there is nothing in this to distinguish the pitch. Next is the sectional or

side view. In this is shown the thickness of the boards and the flare or pitch, which in this is the three-quarter pitch. Following (Fig. 129) is shown the four sides in the collapsible or ready to be put together, followed with the top view of the edge of the board.

Of course it is not necessary to lay out all of this diagram, or any of it for that matter; it is done by way of illustration. See the application of the square, which, in this case, is 12 and 21⅝. But why use these numbers? Because the flare given is the three-quarter pitch, or 12 and 18 on the square, and the hypothenuse of these numbers is 21⅝, the tongue giving the side bevel. When working full scale it is always 12 on the tongue.

For the miter bevel, the top edges should be first beveled so as to be level when in position. The miter would be at an angle of 45°, and any of the equal numbers on the square gives this cut; but if the edges are to be left square with the sides, as shown, the above will not work.

To accomplish this, however, a very simple way is shown in diagram at A, or in Fig. 130 as follows: Lay off the base and the desired pitch, and on the latter measure the thickness of the

board as at AB. From B draw a plumb line to base. BC is the width apart; the side bevels should be along the edge of the board.

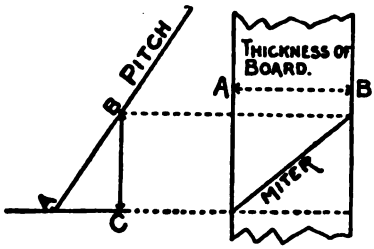


FIG. 130

In case of large hoppers to be built to suit some particular place, or regardless of pitch, it is better to use the one-inch scale as illustrated in Fig. 131. The figures 7½ and 17⅞ give the side cut, while the section gives the miter.

This diagram is all that is necessary to find the cuts for any size hopper, and were it not for the miter even this is unnecessary.

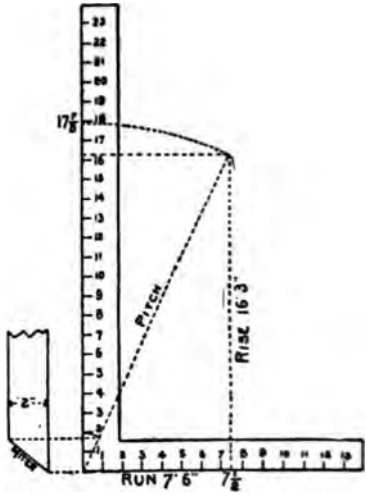


FIG. 131

Another method is here offered which is taken from the old "American Builder," and which many of the older workmen will recognize, as it was at one

me in great favor. The lines E, D, H, A, and

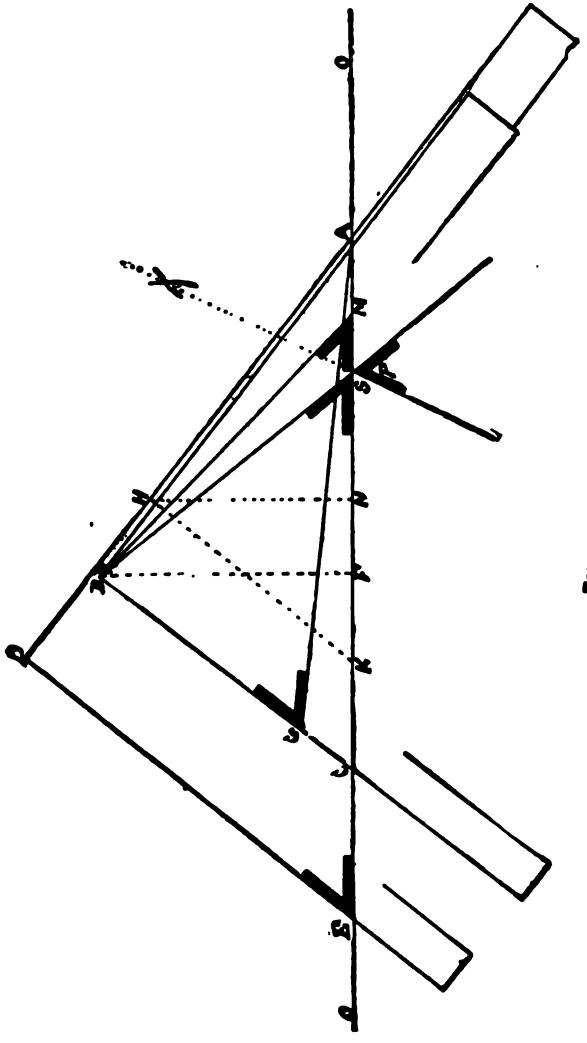


FIG. 138

C, G, B, Fig. 132, show the outside edges of the steel square, or squares; OO is the edge of the board. Half the width of the width of the top less half the discharge hole on the blade AB. The depth on the tongue BC gives the diagonal AC, the width of the side. Make AD on the blade equal AC, and DE on the tongue equal AB, and E is the bevel for face of stuff. Make GB equal FB; connect GA, and G is the miter cut for edge of stuff. Square a line from OO, cutting AB. To save extra lines use FB. Make AH (on AD) equal AF. HK square from AD, and FM equal HK; connect MB, and M is the bevel for straight cut (to nail on, as we nail a box together, square instead of miter), the long point inside. If we make the line cutting at H square from AE instead of AD, as NH and FS equal NH, connect SB, and S is the trying bevel for straight cut. Bisect BSO; draw the miter line and it gives P the trying bevel for miter cut; the lines are extended and bevel P placed below the line for want of room above.

And yet another method: Suppose ABCD, Fig. 133, to represent the elevation of a box, the sides of which have a slope of 45°. Take C as a center and CB as radius, and describe the semi-circle under the line AB, as shown by BEJ.

From C let fall a perpendicular through the line AB, intersecting the semicircle in the point E. Through the point E thus established draw a horizontal line or a line parallel to AB, making it in length equal to AB. From the point F thus established draw FC. Then the bevel at F will be the bevel to be used for the sides of the box or hopper. To find the bevel of miters at the corners with K as center and radius equal to the distance from K to the line CB, describe an arc cutting the line KC, thus establishing the point L. From L draw the line LJ, cutting the line AB at the point J, which represents the intersection of the arc first drawn with the AB. Then the bevel at L is the bevel of the line

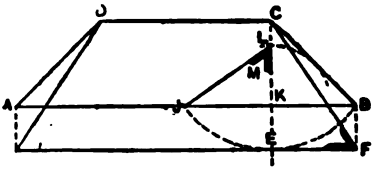


FIG. 133

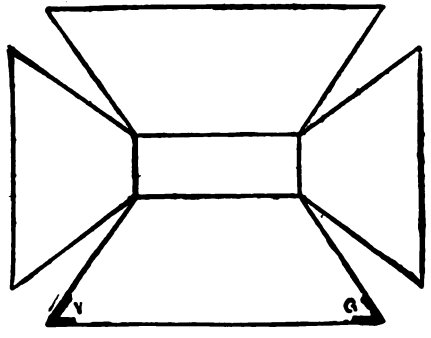


FIG. 134

miters at the corners. Fig. 134 shows the sides of the box laid out flat.

Mr. Woods recently published in the "The National Builder," a paper on bevels and hopper cuts generally, which, owing to its excellency, I have thought worthy of a place in this work. The author starts out by saying: "If there was no given pitch, then the sides would be vertical. Now with 12 on the tongue as center, draw an arc of same radius from the heel to a point directly above and square over the blade;

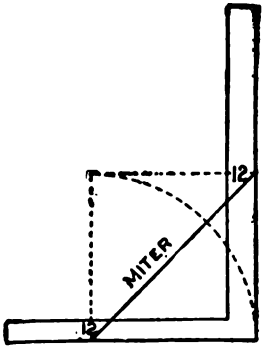


FIG. 135

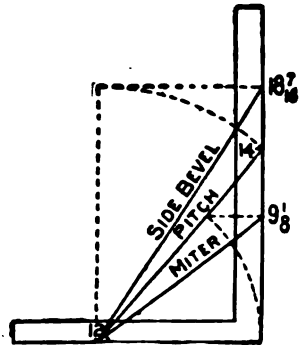


FIG. 136

12 and 12 will give the miter, Fig. 135. Simple enough, but do you know that this simple rule applies when there is a pitch given? At the point where the arc intersects the pitch taken on the blade will give the miter, the blade giving the cut. See Fig. 136.

"For the side bevel across the board, transfer the length of the pitch to the blade, the tongue giving the cut. These figures also give the side cut of the jacks for a roof of same pitch. The blade in this case giving the cut.

"Now we will give another method of finding the miter. In all roofs and hoppers there is an unseen pitch which we will call co-pitch. Assuming that the edges of our boards are square the

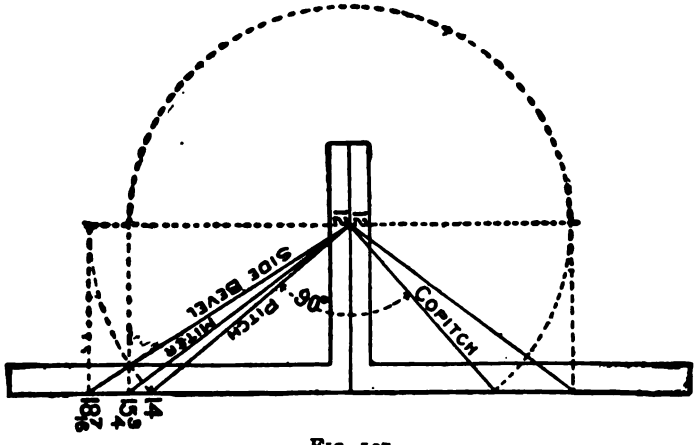


FIG. 137

co-pitch would stand at an angle of 90° with the given pitch." See Fig. 137.

The rule given in Fig. 136 for the side bevel will apply to the miter, but instead of using the length of the given pitch substitute that of the co-pitch, and by referring to Fig. 137 we find this

to be 15¾ inches on the blade. Now for proof, see Fig. 138. Twelve and 9⅛ first method, and 12

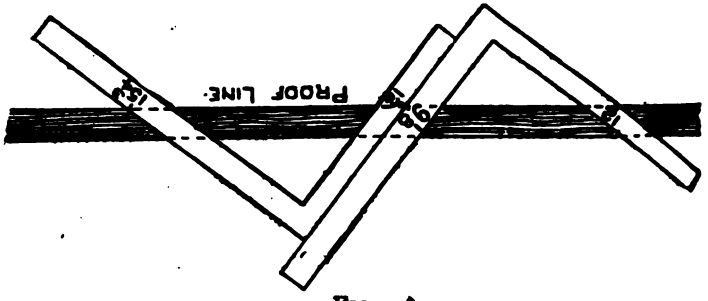


FIG. 138

and 15¾ second method. The blade giving the cut in the former, and the tongue in the latter.

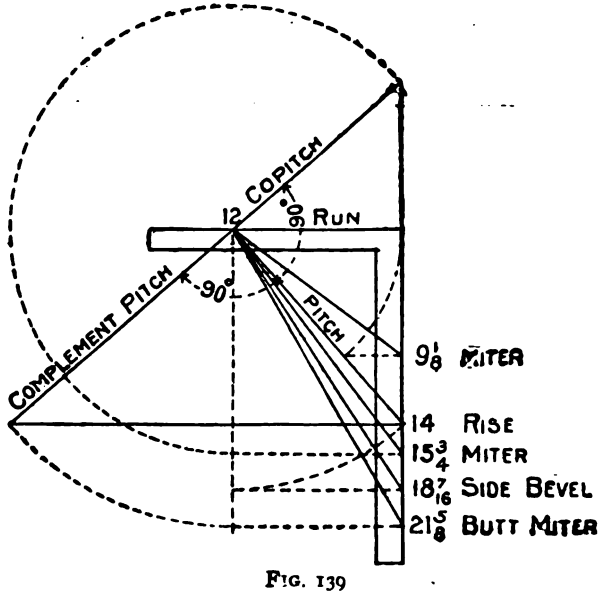


FIG. 139

In Fig. 139 is shown all that is contained in the other figures and then some more. In this we run up against another pitch. It is an extenuation of the co-pitch to a point on a level with the starting point of the given pitch. This we will call complement pitch. The length of this pitch transferred to the blade will give the butt-joint or miter; the tongue giving the cut.

In Fig. 140 is shown a diagram for a hopper of one-half pitch. In this all of the pitches are of equal length. Therefore 12 and 16$\frac{1}{4}$ will give all of the cuts; the tongue giving the cuts in each case. Figs. 139 and 142 are simply fillers and self-explanatory.

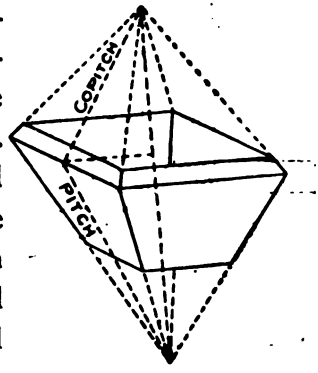


FIG. 140

While editor of the "Builder and Woodworker" of New York, I had considerable communication with the late Robert Riddell whose works in the 60's, 70's, and 80's were very popular, and on one occasion, in 1879, he sent to me the following diagrams and explanation of a method for obtaining the bevels and cuts for nearly all kinds of flared work or inclined framing. This problem and solution, said Mr. Riddell, is offered

for the first time for publication, as a reliable and simple method for obtaining bevels and cuts

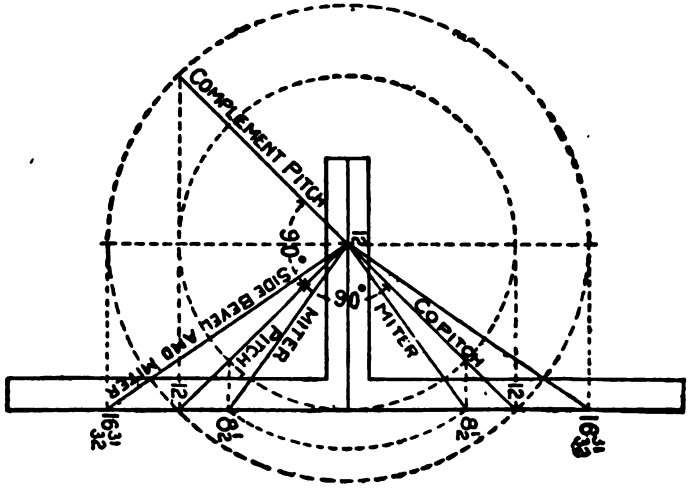


FIG. 141

for nearly all kinds of inclined framing, and for the finding of cuts for splay and flare work.

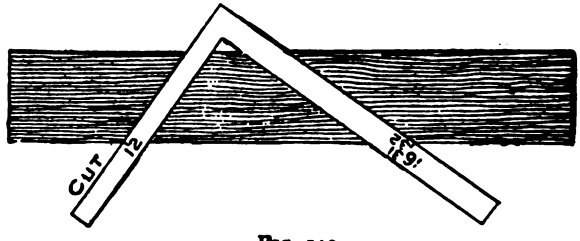


FIG. 142

The diagrams show how the cuts for hopper work may be obtained for angles other than

right ones, also for getting angles for corner posts having a double inclination.

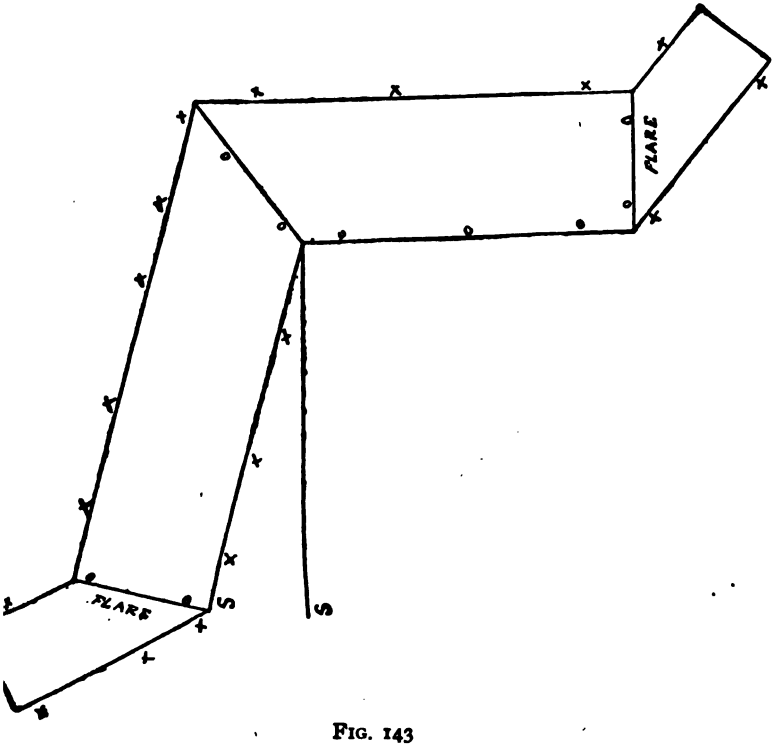


FIG. 143

Let us suppose the plans shown at Figs. 143 and 144 to be right angle figures, having sides which incline or flare equally to any desired angle. A corner post is also used which will incline same as the ends and sides. The junction at the angles may be either mitered or a butt, as either

style of joint may be obtained when desired. T
describe the problem, begin by drawing tw

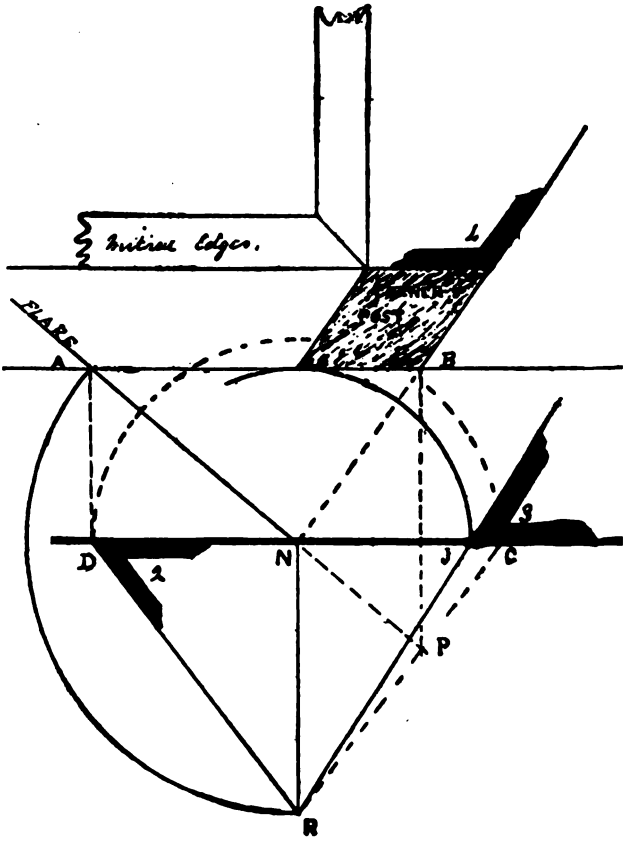


FIG. 144

parallel lines, AB and DC, any reasonable d
tance apart. Assume AC as inclination or fl
of sides. From N square down a line maki

NA and NR equal. From A square down a line cutting D; join RD, and in the angles thus formed find bevel 2 for cut on face of sides

To find the bevel for miter on edge of stuff, take N as a center and describe an arc, touching the line AB and terminating at J. From B draw a line through J indefinitely. This gives bevel 3 for the miter.

To find the corner post, proceed as follows: Make NC equal ND; join RC, and extend AN to cut RC at P, from which square up a line cutting at B. From N draw through B, thus forming both angles of the corner post, and giving bevel 4, which answers either for a butt-joint or the shoulder cuts on cross-rails of framing.

Nothing can be more simple or more accurate than this method, and it may be easily tested by first drawing the "spread out," as shown on the upper part of the diagram on cardboard, and cutting through in the lines marked X, X, X, then fold on the lines marked O, O, O.

Bring the points S, S together, and the mode of construction will readily be understood.

The flare may be any angle, the results will be the same.

Another problem and solution, and I am done. The problem I am now about to present is one

that, when thoroughly grasped by the workman, will enable him to lay out the lines for every conceivable cut required in tapered framing, paneling, or splayed work of any kind when angles are thrown out of square. To Peter Nicholson is due the credit of this method of solution, but, as in many other things, the master hand of the late Robert Riddell improved and simplified it and clothed it in language easily understood by the American workman.

Let us suppose the line AD, at Fig. 145, to be

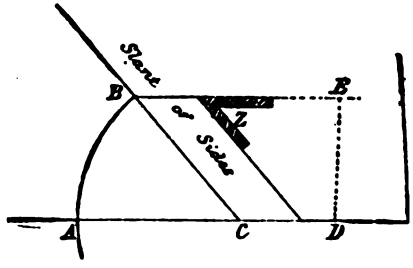


FIG. 145

a given base line on which a slanting side of hopper or box rises at any angle to the base line, as CB, and the total height of the work is represented by the line BE. By this diagram it will be seen that the horizontal lines or bevels of the slanting sides are indicated by the bevel Z.

Having got this diagram, which, of course, is not drawn to scale, well in hand, the ground plan

of the hopper may be laid down in such a shape as desired, with the sides, of course, having the slant as given in Fig. 145.

Take T2, 3S, Fig. 146, as a part of the plan, then set off the width of sides equal to CB, as shown in Fig. 145. These are shown to intersect at PL above; then draw lines from PL through 2-3 until they intersect at C, as the dotted lines show. Take C as a center, and with the radius A describe the semicircle AA, and with the same radius transferred to C, Fig. 145, describe the arc AB, as shown. Again with the same radius, set off arcs AB, AB on Fig. 146, cutting the semicircle at B, as shown. Now draw through B, on the right, parallel with S3, cutting at J and F; square over FH and JK, and join HC; this gives bevel X as the cut for face of sides which come together at the angles shown at 3. The miters on the edge of stuff are parallel with the dotted line L3. This is the acute corner of the hopper, and as the edges are worked off to the bevel Z, as shown in Fig. 145, the miter must be correct.

Having mastered the details of the acute corner, the square corner at S will be next in order. The first step is to join KV, which gives the bevel Y for the cut on the face of sides on the ends which form the square corners. The

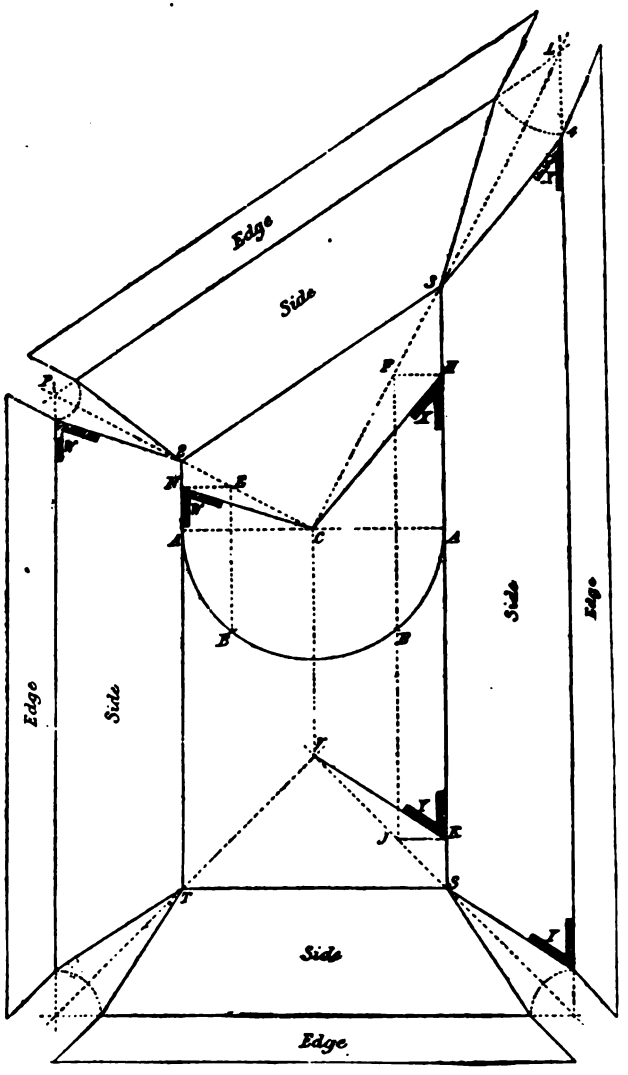


FIG. 146

method of obtaining these lines is the same as that explained for obtaining them for the acute angled corner as shown by the dotted lines. As the angles S T are both square, being right and left, the same operation answers both; that is, the bevel Y does for both corners.

Coming to the obtuse angle P2, we draw a line BE on the left parallel with A2, cutting at E, as shown by dotted line. Square over at E, cutting TA2 at N; join NC, which will give the bevel W, which is the angle of cut for face of sides. The miters on edges are found by drawing a line parallel with P2.

In this problem, like the previous one, every line necessary to the cutting of a hopper, after the plan as shown by the boundary lines 2, 3, T, S, is complete and exhaustive; but it must be understood that in actual work the spreading out of the sides, as here exhibited, will not be necessary, as the angles will find themselves when the work is put together. When the plan of the base—which is the small end of the hopper in this case—is given, and the slant or inclination of the sides known, the rest may easily be obtained. In order to become thoroughly conversant with the problem, I would advise the reader—as has often been before advised by

teachers—that it would be well to have the drawing made on cardboard, so as, by cutting out all the outer lines, including the open corners which form the miters, to leave the whole piece loose. Then make slight cuts in the back of the cardboard, opposite the lines 2, 3, S, T, just deep enough to admit of the cardboard being bent upward on the cut lines without breaking. Then run the knife along the lines which indicate the edges of the hopper sides. This cut must be made on the face of the drawing, so as to admit of the edges being turned downward. After all the cuts are made, raise the side until the corners come closely together and let the edges fall level, or in such a position that the miters come closely together. If the lines have been drawn accurately and the cuts made on the lines in a proper manner, the work will adjust itself nicely and the sides will have the exact inclination shown at Fig. 145, and a perfect model of the work will be the result.

Before leaving the subject of "Bevels, Splays, and Hoppers," I wish to call the attention of my readers to Figs. 143 and 144, in order that they may get a clear understanding of the manner of getting the bevels for corner posts for hoppers. The methods of determining the proper bevels

and angles for those posts are set forth at considerable length in the text and drawings, and what I desire to show is that the corner post of a hopper is exactly, in miniature, similar to the corner post of a frame building having a double inclination; or, in other words, a tapered building, with the exception that a hopper has its smallest area as a base, while a tapered building, a pyramid, has its largest area as a base.

Now it must be evident that the lines giving the proper angles and bevels for the corner post of a hopper must of necessity give the proper lines for the corner post for a pyramidal building, such as a railway tank frame, or any similar structure. True, the position of the post is inverted, as in the hopper its top falls outward, while in the timber structure the top inclines inward; but this makes no difference in the theory, all the operator has to bear in mind is that the hopper in this case is reversed. Once the proper shape of the corner post has been obtained, all other bevels can readily be found, as the side cuts for joists and braces can be taken from them. A study of these two figures in this direction will lead the student up to a correct knowledge of tapered framing.

I leave the subject of splays and bevels here,

but I may add that I have not, by any means, shown all the ways and means of finding solutions of problems presented, but I am persuaded the examples I have set forth are the best suited for the workmen of this country because of their simplicity and of the manner in which they have been laid down. I think every possible kind of hopper and splay has been touched upon, and, if not, I am sure the rules given will enable any workman who has followed me closely to deal with the difficulty successfully.

At Fig. 147, I show one of the usual methods of finding the circumference of a circle; this is

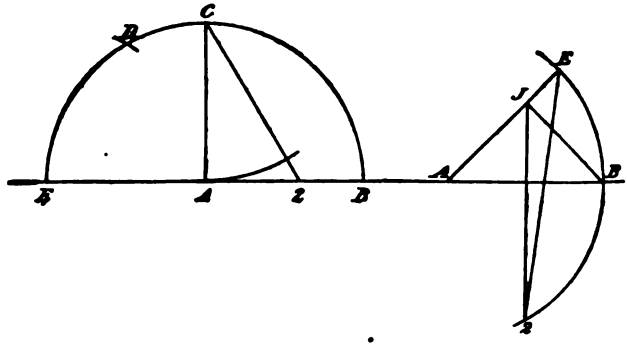


FIG. 147 FIG. 148

done by taking the radius AB on the compass, and with E as a center intersect the curve in D; then with the same radius, and C as a center, draw the arc from A, making it and DC equal;

draw from C, through the point, cutting in 2, which gives 2E as one-fourth of the circumference of a circle having AB as a radius. The same result can be obtained almost instantly by using a set-square having an angle of 60° and with it draw a line from C which will cut the diameter at 2.

It is generally supposed that this method is a correct one, or at least sufficiently so for practical purposes. It is not so, however, and when used sometimes leads to error and trouble.

A much more accurate method is shown at Fig. 148, which is obtained as follows: Take A as center and with B as a radius, describe the arc, and from A, with an angle of 45°, draw a line cutting at E; with the same angle draw BJ; from J draw square with AB cutting the arc in 2; join it with E, then four times 2E will be found to be equal to the circumference of a circle having the radius AB.

Suppose the diameter 2B of the circle shown at Fig. 149, to be 16 feet in diameter; make a similar figure on a scale of one-quarter of an inch to the foot, then the exact circumference of this may be found by drawing AE with the angle 45°; then with the same angle draw BR, and from R draw square with AB cutting the circle in D;

join it and E, and four times this line DE will be equal to the circumference of the circle. This may be proven as follows: Join B, E, then draw E parallel with the diameter cutting the perpendicular in J; draw through R parallel with JE cutting in F and H; join J, D, and we have AB, which divided the circumference into six equal parts; i.e., DC7, BE8, FH9, AC10, KJ11, NP12, BL13, PR14, and BC into 16 parts. This diagram also gives the lengths of chords which divide the circle into equal parts and proves the accuracy of the line DE, as four times this line will be the circumference.

Now comes in the steel square, where these dimensions may be worked out without drawing a line. Looking at Fig. 149 we find that the lines DJ and DR form an angle in which is a bevel marked X which plays an important part in the next illustration.

Let EB on the blade of the square, shown at Fig. 150, be the radius of the circle; lay a straight-edge across the square, keeping one edge on the point E, then apply the bevel X, as shown, to the blade of the square so that the blade of the bevel will align with the edge of the straight-edge; then the distance BR on the blade will be twice the length of DE, Fig. 149,

and consequently equal to half the circumference of the circle.

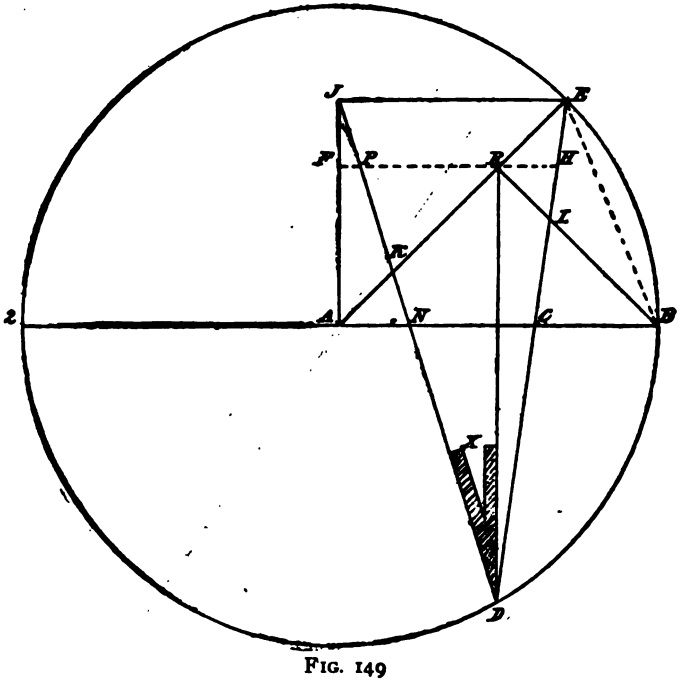


FIG. 149

To find the figures on the square that shall give an angle equal to that of DJE, Fig. 149, in which is seen that bevel X, lay a straight-edge across the square, keeping the edge to the mark 9½ on the blade and 3 on the tongue; then the angles thus formed by the straight-edge and the square will be found to exactly agree with that of bevel X, which was obtained by the geomet-

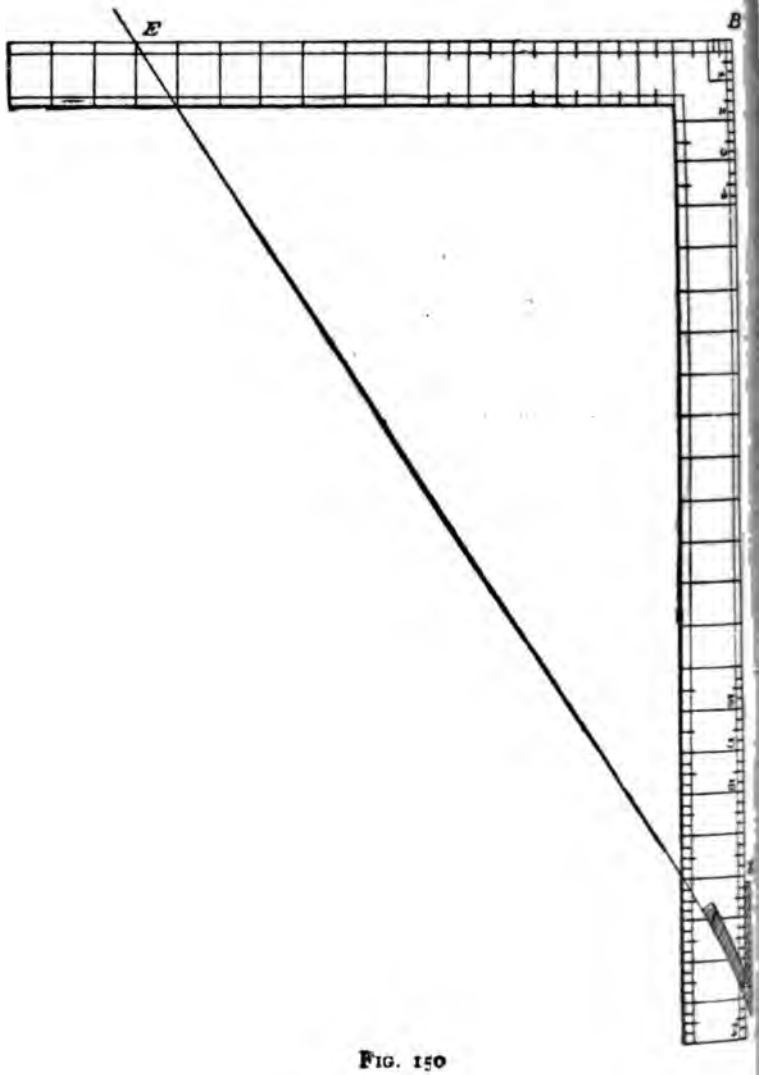


FIG. 150

rical construction of Fig. 149. This is a useful problem and may often be put to practical use.

To divide a line of any length into any number of equal parts by the steel square, we proceed as follows: The heel, or external angle of the square, is shown at A, Fig. 151. Take line No. 1, which may be made to half-inch scale, and we find it will measure 17 feet 6 inches, which is required to be divided into thirteen parts. To do this, let AB on tongue of square equal AB on the right; make A5 on blade of square measure 6½ inches, or thirteen halves, which are equal to the number of parts required. Draw line 5B; make 5L equal one-half inch; from L square over a line cutting in N; then LN divides line No. 1 into thirteen parts, length of each 1'4".

Take line No. 2. This measures, by a quarter-inch scale, 31 feet 5 inches. It is required to be divided into 22 parts. To do this, let AC on tongue of square equal AC No. 2, on the right, and A4 on blade of square measure 5½ inches or 22 quarters, which is equal to the number of parts required. Draw line 4C; make 4R equal ¼ inch; from R square over a line cutting in K. This gives RK, which will divide line No. 2 into 22 parts as required. Length of each 1'5".

No. 3 on the right. This line measures, by a

quarter-inch scale, 26 feet 6 inches. It

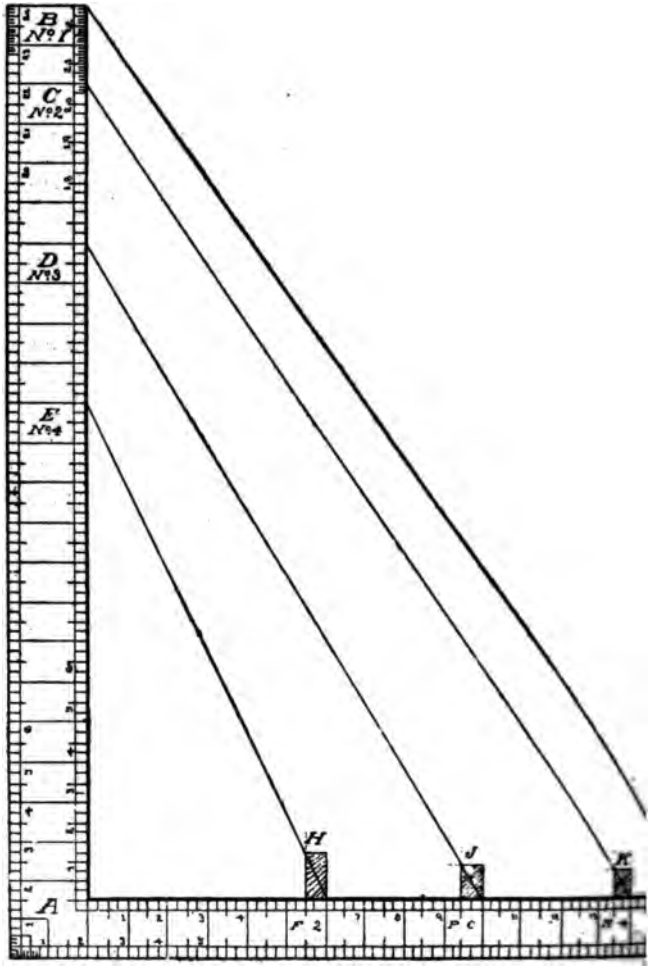


FIG. 151

required to be divided into 17 parts. To do this, make AD on tongue of square equal AD, No. 3 on the right, and A3 on the blade of square to measure 4¼ inches or 17 quarters; that being the number of parts required. Draw line 3D; make 3P equal ¼ inch; from P square over a line cutting in J; then PJ divides line No. 3 into 17 parts. Length of each 1′7″.

No. 4 on the right. This line measures, by a quarter-inch scale, 23 feet, and it is required to be divided into 11 parts. This is done by making AE on tongue of square equal AE, No. 4 on the right. Let A2 on blade of square measure 11 quarter inches, that being the number of parts required; draw line 2E; make 2F equal ¼ inch; from F square over a line cutting in H; then FH divides lines No. 4 into 11 parts. Length of each 2′ 1 1/11″.

In dividing a space of any great extent, the quarter-inch scale will be found most convenient. To give a practical illustration: Suppose a line to be 96 feet long, and it is required to be divided into 48 parts. Begin in a systematic way by squaring over a line on the surface of a board, and from its edge mark one foot on the line; one foot being equal to 48 inches. Next, measure two feet from the line along the edge of

board, two feet being equal to 96 quarter inches. Now proceed to find one part that will divide 96 feet into 48 parts. The answer is given by the method just explained.

A little thought will enable the student to use any scale that is divisible by the divisions and subdivisions laid down on the steel square, a matter that will enable him to divide lines of almost any length.

When we know the side of a square we can readily find its diagonal by the steel square as follows: Suppose AB, Fig. 152, be the side of a square which measures, by a quarter-inch scale, 6 feet 10 inches. To find its diagonal, draw the line BC to the angle 45°; take A as center and strike an arc touching line BC, cutting in V. Join V, C. This gives bevel W; let it be applied to the square, Fig. 153, and at the distance AB, which is equal to the side of given square, lay a straight-edge against the blade of bevel and the line made by it cuts in mark C on the square, giving AC for the diagonal, which measures 9 feet 7 inches. This agrees exactly with line PR or BC, Fig. 152.

Now let it be required to give the diagonal of a square, the sides of which are equal to A2, and measure 10 feet 6 inches; find its diagonal at

Fig. 153 by making A2 equal the side of square; let bevel W and the straight-edge be appl'ed as

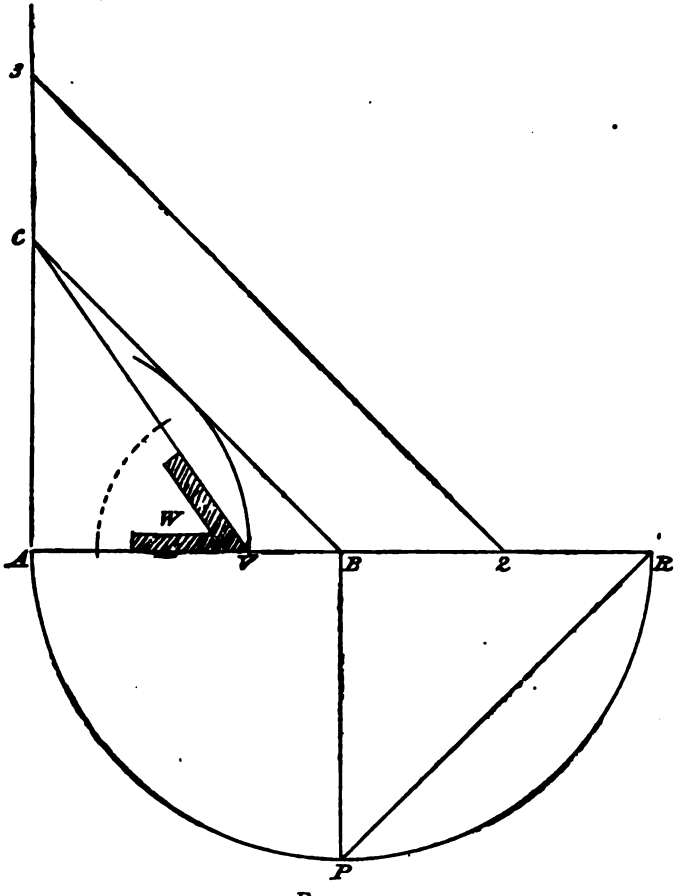


FIG. 152

before; then the line from 2 cuts mark J on the square, giving AJ for the diagonal, which meas-

ures 14 feet 8 inches; this agrees with diagonal 2-3, Fig. 152.

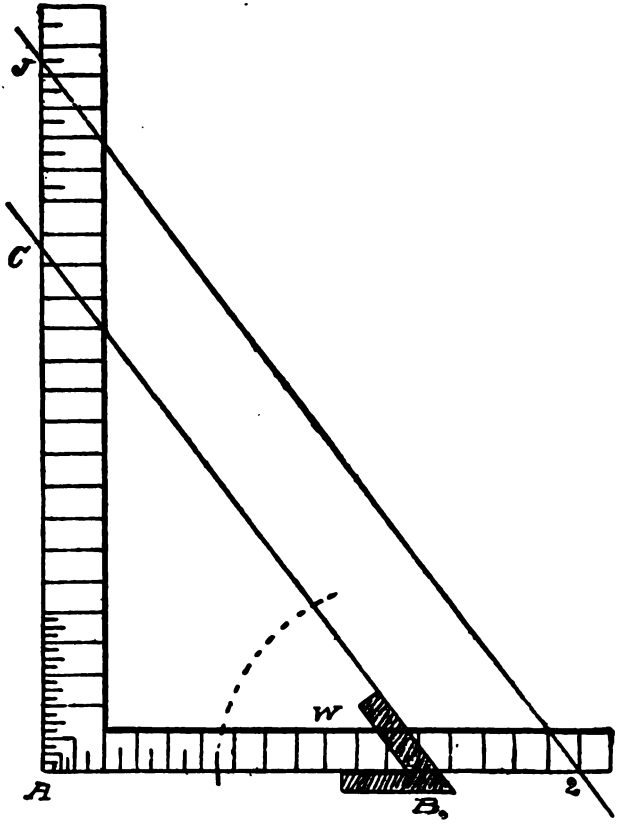


FIG. 153

Similar results may be obtained without ar drawing by merely finding the numbers on th blade and tongue of a square that will agree c

:qual the angle in bevel W; then let the bevel ıs now set be applied to the square, and we find :hat the blade of bevel agrees with mark 4"⅞" ɔn tongue of square and 6"⅞" on the blade; so :hat the diagonal of any square being required, .t is easily obtained by setting a bevel in the manner stated. The answer will be correct by :he angle in the bevel being accurate.

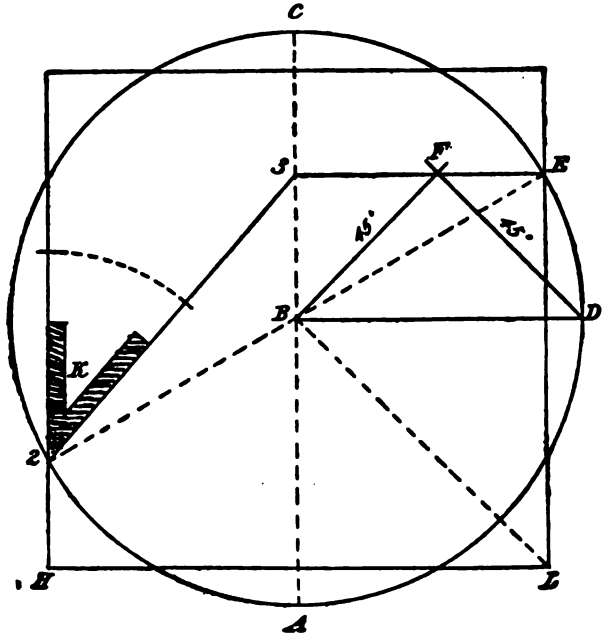


FIG. 154

Fig. 154 shows a construction which might be :alled an attempt at squaring the circle. Its

solution has been thought an impossibility, and with all due regard to the opinion of others on this point, we think it quite possible to solve this difficult problem by a new and simple method of construction, which is here given.

The diameter of the circle measures 12 feet. From center B draw line BD at right angles with the diameter; draw from B and D, with the angle 45°, intersecting in F; through F draw 3E parallel with BD; draw through E parallel with the diameter, and from center B draw parallel with FB cutting line from E in L; and from L draw parallel with BD; also from E draw through center B, cutting in 2; draw through 2 parallel with the diameter cutting line from L in H, and we have now three sides of a square; the fourth, being made equal to one of these, completes a square, the area of which will be found equal to that of the circle; its diameter being 12 feet, and one side of the square 10 feet 5 inches.

To remove all doubt as to the correctness of this solution, let us prove it in another way, by a right angle, or the steel square, shown at Fig. 155. Here make the distance AC equal the diameter of the circle; lay a straight-edge across the square, keeping its edge on point C. Take bevel K in the angle HAC and apply it

to point C; bring the straight-edge against the blade of bevel, and we find a line cutting the

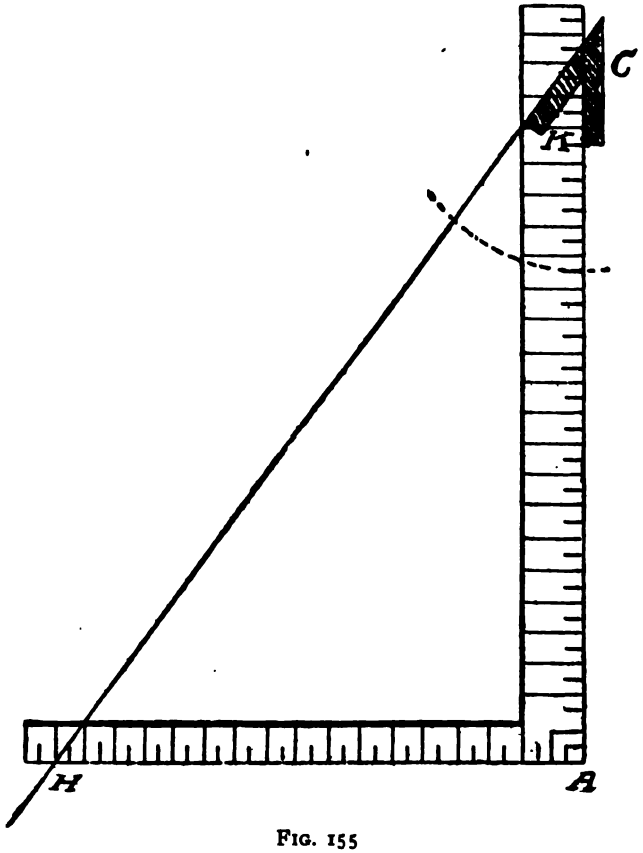


FIG. 155

right angle at point H, giving the distance HA, which exactly equals one side of the square HL, Fig. 154, thus giving the same result by two different methods.

The utility of the steel square is now evident; by it the measurement of any surface may be instantly given, and by the same means we can find the capacity of anything round or square. All that is necessary is to set the bevel to a certain number of parts or inches on the blade and tongue of the square. To explain this point, take bevel K as now set, and apply its stock against the blade of square; move the bevel until the blade cuts some members on the square that will correspond with the angle of the bevel; its blade agrees with marks 5″⅞″ and 5″⅛″, or 6″¾″ and 5″⅛″; either of these numbers will answer. The bevel being set in the manner stated, will not require any alteration, let the diameter of the circle be what it may.

In a previous diagram I explained how this problem might be worked out by a different method. Both are correct, and the reader may adopt either one or the other.

I will now endeavor to show how the square may be used in getting certain dimensions without much effort. Suppose we wish to find the superficial contents of a board or other material that is not more than one inch thick, we proceed as follows: Let Fig. 156 represent the square. The blade and tongue may be divided into any

umber of parts by scale. We may call a $\frac{1}{12}$, r an $\frac{1}{8}$ or a $\frac{1}{4}$, etc., a foot, just as we wish to

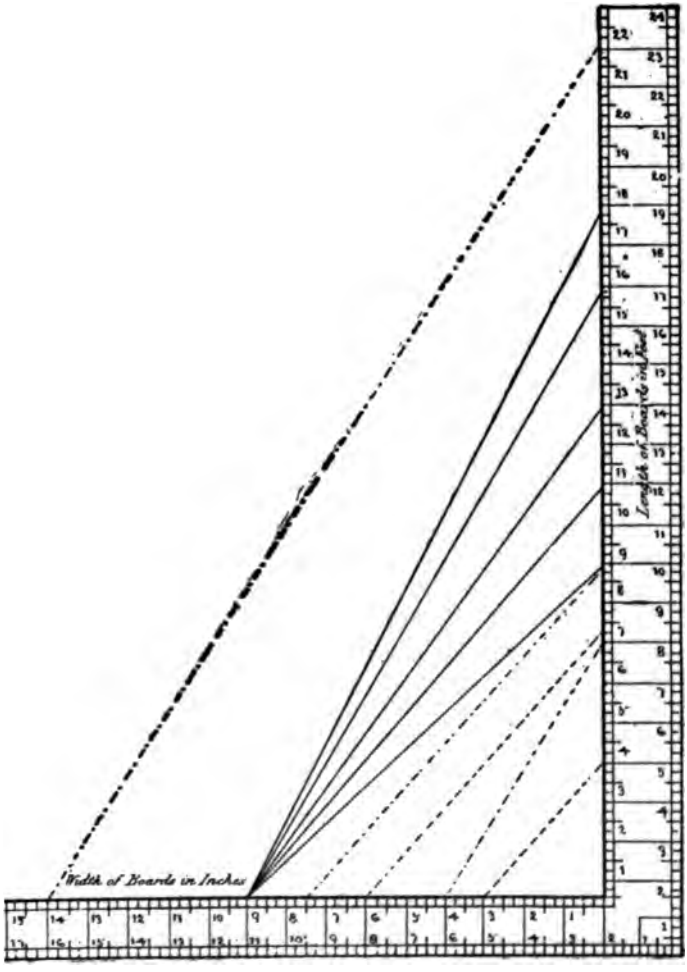


FIG. 156

meet the condition. Let the point 12 or 6, where the lines most converge, be a fixed point. Now assume a board to be 26 feet long and 6 inches wide. We know that the surface measurement of it is exactly 12 feet. The same result is given by the right angle. For example, draw the line 12-26, and parallel to it draw from the 6-inch mark. The line cuts in 13 feet, which is the answer.

Find the measurement of a board 21 feet long and 19 inches wide. Draw the line 12-21, and parallel to it draw from the 19-inch mark. The line cuts in $33\frac{3}{10}$ feet, which is the answer.

Give the measurement of a board 18 feet long and $10\frac{1}{2}$ inches wide. Draw the line 12-18, and parallel to it draw the $10\frac{1}{2}$-inch mark. The line cuts in $15\frac{3}{10}$ feet, which is the answer.

Find the measurement of a board 18 feet long and 9 inches wide. The line 12-18 being already given, draw parallel to it from the 9-inch mark; and this line cuts in 13 feet 6 inches, which is the answer.

What is the surface measurement of a board 29 feet long and 4 inches wide? Draw the line 12-29, and parallel to it draw from the 4-inch mark. The line cuts in 10 feet, which is the answer.

In the foregoing it will be seen that the scale used is less than one inch; but whatever the scale, it must be made to represent an inch in the end; thus, if we use ½ inch, then we must multiply the result by 2 to make it into inches, and if we use a quarter-inch scale, then multiply by 4, and so on, in order to make the result into feet and inches.

To reduce surface measure to square yards by aid of the square, we proceed as follows: There are 9 square feet in 1 square yard, as shown in Fig. 157, so we make 9 a constant number in this problem. Let us suppose any of the regular divisions of the square 1 yard in length; be it a ¼-inch, 1-inch, or any other division. To designate the sides, call the perpendicular *blade* of square, and lower line *tongue* of square, and A the internal angle. Let 9B, Fig. 158, be the fixed point, and from it draw the perpendicular, which divide into any number of parts, each to equal those on the right angle.

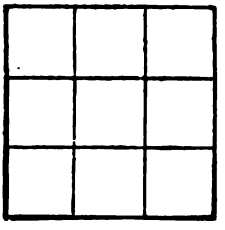


FIG. 157

It is now required to give the number of square yards in a floor 22 feet long and 15 wide. Draw the line 9-22-H, and parallel to it draw from mark 15E cutting in H. This gives 14⅔, to which add

22, making 36⅔ square yards of floor, which is the answer.

How many square yards of carpet will cover a floor 18 feet long and 13 wide? Draw the line 9-18-L, and parallel to it draw from mark 13-D cutting in F. This gives 8, to which add 18, making 26 square yards of carpet, which is the answer.

To find the number of square yards in a floor which is 15 feet long and 11 wide. Draw the line 9-15-K, and parallel to it draw from mark 11-C cutting N. This gives 3⅓, to which add 15, making 18⅓ square yards in the floor; this is the answer.

Now give the number of square yards on the surface of a counter which is 10 feet long and 7½ wide. Draw the line 9-10-R, and parallel to it, draw from mark 7½-P cutting in J. This gives 8½ square yards on the surface of counter, which is the answer.

It is now evident that the steel square may be made to give many other useful and practical ideas, besides those which have been shown.

THE SQUARE IN HANDRAILING

For over 25 years I have felt certain that some genius will arise and show the world how

all kinds of handrailing may be "laid out" by the use of the steel square alone. I have wrestled with the subject often and long, but it has so far eluded me, though in a hazy way I have been able to get a glimpse of the relation between the square, the rise and tread, and an oblique cut cylinder. I know that a relation exists, and that relation and its perfect rendering will be discovered some of these days by a steel square expert; and a fortune awaits the man who makes the discovery and gives it to the public.

This may seem heretical to the old time handrailer who has waded through the mazy paths as marked down by the old master-hands of the science, and they may well be forgiven if they turn up their scientific noses at what I have said in this matter, and sneeringly call it so much "bosh." If thirty years ago any person had predicted that the steel square could be made to accomplish what it now can in good hands, the prophet would have been set down as a foolish fellow, and his predictions "all bosh." Yet we see what has been done, and knowing what I do regarding the capabilities of the square, I do not hesitate for a moment regarding my reputation as a prophet when predicting that all circular and elliptical handrails will be laid out

altogether by aid of the steel square and a piec
of string before the end of the first quarter o

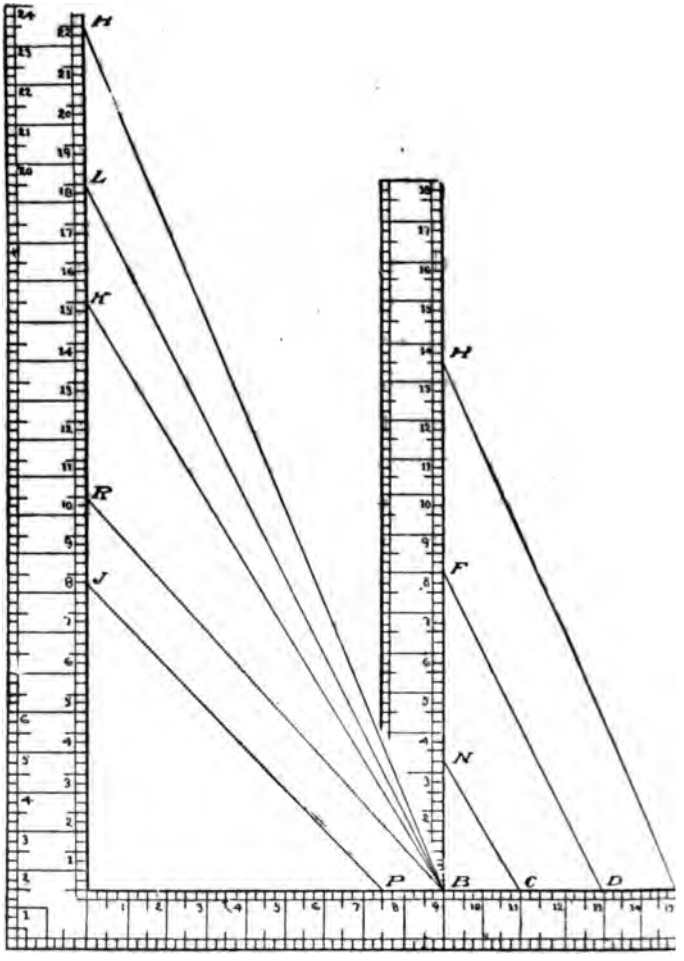


FIG. 158

the twentieth century. With this certainty before me, I urge all young men, and old ones too, to sometimes try and find the method I refer to. That it exists in the unseen land I am as confident as I am of penning these lines, and to the man who makes the discovery fame and wealth will be the reward.

As an item in this direction, I give the following, which is by Mr. Penrose of England, and which was sent me for publication in this work. I had reached this point myself some years ago, but described it a little differently; but think on the whole, Mr. Penrose's way of putting it is perhaps better than mine, so give it as it came to me.

In getting out face molds it has generally been considered necessary first to unfold the tangents and get the heights, and by construction get the bevels. This method is somewhat different, though results are the same, but are produced more expeditiously,—a steel square, a pencil, and a pair of compasses being used. Take, for illustration, a side wreath mitered into the newel cap. The distance the newel stands out of line with the straight rail is usually governed by the width of the hall, but where there is plenty of room it is a matter of taste. The

distance the easement runs back is also a matter of choice. The method will apply no matter where the newel is placed, or whether the easement is less or more than the one step of the example illustrated. What is meant by one step is, that the tangent of the straight rail continues

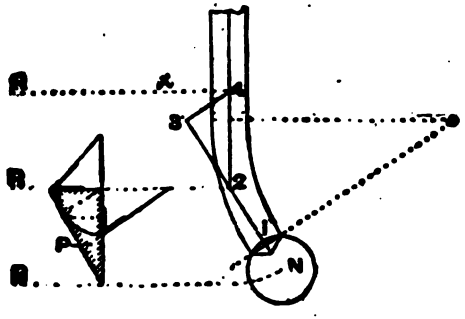


FIG. 159

to the point 2, Fig. 159. The tangent 2-1 is level.

To produce the face mold, lay the steel square in the position indicated by the lines 1, 2, 3, 4, not the figure on the square at the points numbered, and transfer them to a piece of thin stuff,

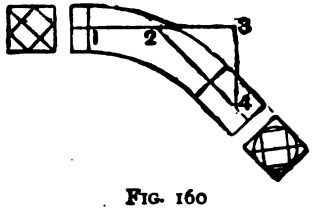


FIG. 160

Fig. 160. Line 3-4 in Fig. 160 is indefinite. Now take the length of the long edge of the pitch board in the compasses, and with point 2, Fig. 160, as a center, cut the line 3-4 in 4 and draw 2-4

Now 1-2 is the level, and 2-4 is the pitch tangent on the face mold.

To get the bevels and width of the face mold at both ends, take the distance 3-4 on the blade of the square, and the height of a riser on the tongue of the square, apply to the edge of a board and mark by the tongue; this gives the bevel for the lower end of the wreath. Mark the width of the rail on the bevel; this gives the width of the mold at the lower end.

Next take the distance 4-x on the blade of the square, and the distance shown on the pitch board by the line squared from its top edge to the corner, on the tongue of the square; apply to the edge of a board and mark by the tongue; this gives the bevel for the top end of the wreath. Mark the width of the rail on the bevel, and this gives the width of the mold at the top end. An allowance of 6 inches is made at the top end to joint to the straight rail, and 2 inches at the bottom end to form the miter into the newel cap. The springing line is taken from the pitch board.

Fig. 159, in which are shown the bevels and the pitch board will help to make clear the method used. The bevel at the back of the pitch board is for the bottom end of the wreath. The triangle has for its base the line 3-4, and for

its height one riser. The hypothenuse is the length of 3-4, Fig. 160, and Fig. 160 stands over Fig. 159, level on the line 1-2-3, and inclined from it in this cast at an angle of nearly 45°.

The top end bevel is shown below the pitch board. The angle has for its base the distance 4-x, and for its height not one riser but the length of a line, from the corner of the pitch board squared from its top edge. This bevel will be understood better by placing the pitch board on the line 2-4 and applying the small triangle to it with its base on the line 4-x, and its point even with the top edge of the pitch board. It will then be at right angles to the top edge of the pitch board.

In practice, a parallel mold is generally used, and the wreath piece is cut out; both thickness of plank and width of molding being equal to the diameter of a circle that will contain a section of finished rail.

This is a good beginning, and if this much can be accomplished by the square, why not more on the same lines?

In the earlier part of this work I have shown how the square may be employed in laying out strings for stairs, step ladders and similar work, and if a method or system for setting out hand-

rails for circular and elliptical stairs by the square can be evolved, then nearly the whole science of carpentry and joinery may be developed and explained by aid of that wonderful instrument, the American steel square.

TABLES

In the following tables are all the cuts necessary for obtaining the proper bevels to cut common rafters, hips, jacks, valleys and purlins, either by degrees or by the use of the steel square, for six different pitches, namely, quarter-pitch, one-third pitch, three-quarter pitch, half-pitch, one and a quarter-pitch, and one and a half-pitch.

The figures to be employed on the square to get the proper bevels, are in the last column, right hand side of the tables.

TABLE 1

QUARTER-PITCH ROOF

27 Degrees, or 6-inch Rise to 12-inch Run

DESCRIPTION.	Pitch in Inches.	Pitch in Degrees.	Vertical cut in Degrees.	Horizontal cut in Degrees.	Horizontal cut in Inches.	Vertical cut in Inches.
Common Rafter..	12×6	27	60	27	12×6	Sq. of 12×6
Hips.....	12×4½	18¾	71¼	18¾	12×4½	" 12×4½
Jacks.....	12×6	27	60	42	12×10¾	" 12×6
Valleys.....	12×4½	18¾	71¼	18¾	12×4½	" 12×4½
Purlins Vertical..	.....	...	45	90	Square	" 12×12
Purlins to Plane of Roof	... .	...	65¼	134	12×13	" 12×5¼

TABLE 2

ONE-THIRD PITCH ROOF

34 Degrees, or 8-inch Rise to 12-inch Run

DESCRIPTION.	Pitch in Inches.	Pitch in Degrees.	Vertical cut in Degrees.	Horizontal cut in Degrees.	Horizontal cut in Inches.	Vertical cut in Inches.
Common Rafter..	12×8	34	56	34	12×8	Sq. of 12×8
Hips.....	12×5⅝	25	65	25	12×5⅝	" 12×5⅝
Jacks	12×8	34	56	40	12×10	" 12×8
Valleys.....	12×5⅝	25	65	25	12×5⅝	" 12×5⅝
Purlins Vertical..	.....	...	45	90	Square	" 12×12
Purlins to Plane of Roof	.....	...	60½	132	12×14½	" 12×6½

TABLE 3

THREE-QUARTER PITCH ROOF

37 Degrees, or 9-inch Rise to 12-inch Run

DESCRIPTION.	Pitch in Inches.	Pitch in Degrees.	Vertical cut in Degrees.	Horizontal cut in Degrees.	Horizontal cut in Inches.	Vertical cut in Inches.
Common Rafter..	12×9	37	53	37	12×9	Sq. of 12×9
Hips	12×6¼	27¼	62¾	27½	12×6½	" 12×6½
Jacks	12×9	37	53	39	12×9⅜	" 12×9
Valleys.....	12×6¼	27¼	62¾	27½	12×6½	" 12×6½
Purlins Vertical..	.....	...	45	90	Square	" 12×12
Purlins to Plane of Roof	.....	...	58½	130½	12×14⅞	" 12×7⅛

TABLE 4

ONE-HALF PITCH ROOF

45 Degrees, or 12-inch Rise to 12-inch Run

DESCRIPTION.	Pitch in Inches.	Pitch in Degrees.	Vertical cut in Degrees.	Horizontal cut in Degrees.	Horizontal cut in Inches.	Vertical cut in Inches.
Common Rafter..	12×12	45	45	45	12×12	Sq. of 12×12
Hips.....	12×8½	34½	55	34½	12×8½	" 12×8½
Jacks.....	12×12	45	45	36	12×8½	" 12×12
Valleys.....	22×8½	34½	55	34½	12×8½	" 12×8½
Purlins Vertical..	.....	...	45	90	Square	" 12×12
Purlins to Plane of Roof	.....	...	54	127	12×16½	" 12×8½

TABLE 5

ONE AND ONE-THIRD PITCH ROOF

54 Degrees, or 16-inch Rise to 12-inch Run

DESCRIPTION.	Pitch in Inches.	Pitch in Degrees.	Vertical cut in Degrees.	Horizontal cut in Degrees.	Horizontal cut in Inches.	Vertical cut in Inches.
Common Rafter..	12×16	54	36	54	12×16	Sq. of 12×16
Hips.....	12×11⅓	44	44	44	12×11⅓	" 12×11⅓
Jacks.....	12×16	54	36	32	12×7⅛	" 12×16
Valleys.....	12×11⅓	44	44	44	12×11⅓	" 12×11⅓
Purlins Vertical..	.....	...	45	90	Square	" 12×12
Purlins to Plane of Roof	.....	...	51	132½	12×19½	" 12×9⅓

TABLE 6

ONE AND ONE-HALF PITCH ROOF

57 Degrees, or 18-inch Rise to 12-inch Run

DESCRIPTION.	Pitch in Inches.	Pitch in Degrees.	Vertical cut in Degrees.	Horizontal cut in Degrees.	Horizontal cut in Inches.	Vertical cut in Inches.
Common Rafter ..	12×18	57	33	57	12×18	Sq. of 12×18
Hips	12×12⅝	46	44	46	12×12⅝	" 12×12⅝
Jacks	12×18	57	33	30	12×6¾	" 12×18
Valleys	12×12⅝	46	44	46	12×12⅝	" 12×12⅝
Purlins Vertical ..	.....	...	45	90	Square	" 12×12
Purlins to Plane of Roof	.....	...	50	120	12×21	" 12×10

I have given the pitches of those roofs which are more generally used than any other, though the same rules which obtained the above figures could be continued indefinitely. It has been thought, however, that the foregoing examples were quite sufficient for all ordinary purposes.

In these tables it will be seen that the bevels for purlin cuts have been given, both when the purlin is square or plumb with the horizon, and when it sits with one of its sides against the rafters, or inclined with the roof. The square is made to produce all these bevels.

FOR ESTIMATING CONTENTS OF RAFTERS

In the earlier pages of this work, I promised to publish a table wherein the contents of rafters might be estimated without being obliged to take actual measurements of the timbers, and to this end the annexed table, No. 7, is presented.

In the lengths given, there is no provision made for projections over eaves, or for ridge poles. The measurements are from the face of the plate to the point of ridge. The length of any rafter is given for roofs having a pitch of one-quarter to one-half, and a span of from 8 feet to 50 feet. No provision is made for fractions of feet in width of building.

The length of the rafter being obtained, and its sectional area being known, the contents may readily be found: Thus, suppose width of building to be 34 feet, rafters to be 2x6 inches, sectional area; pitch 9-inch rise; then we have length of rafter by table, is 21 feet 3 inches, and as each foot in length of a rafter 2x6 inches contains one foot board measure, we have 21 feet 3 inches as the amount of material in each rafter, board measure. So with all the other dimensions in the table. The lengths of rafters are given. Determine the sectional areas of rafters, and the contents may easily be found:

TABLE 7

LENGTH OF RAFTERS

In Feet, Inches and Fractions of an Inch

Width of Building in Feet.	Run of Rafters.	6-Inch Rise.		7-Inch Rise.		8-Inch Rise.		9-Inch Rise.		10-Inch Rise.		11-Inch Rise.		12-Inch Rise.		13-Inch Rise.		14-Inch Rise.		15-Inch Rise.		16-Inch Rise.	
	ft.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
8	4	4	5 5/8	4	7 1/8	4	9 3/4	5		5	2 1/8	5	5 1/8	5	7 7/8	5	10 3/4	6	1 3/4	6	4 7/8	6	8
10	5	5	7 1/8	5	9 1/2	6	0 1/4	6	3	6	6 1/4	6	9 3/8	7	0 3/4	7	4 1/2	7	8 1/4	8		8	4
12	6	6	8 1/2	6	11 3/8	7	2 1/2	7	6	7	9 3/8	8	1 5/8	8	5 7/8	8	10 1/2	9	2 5/8	9	7 1/4	10	
14	7	7	10	8	1 1/4	8	6	8	9	9	1 1/4	9	6	9	10 3/4	10	3 7/8	10	9 1/2	11	2 1/4	11	8
16	8	8	11 3/8	9	3 1/8	9	7 3/4	10		10	5	10	10 1/4	11	3	11	9 1/2	12	3 1/8	12	9 5/8	13	4
18	9	10	0 1/4	10	5	10	9 1/2	11	3	11	8 5/8	12	2 1/2	12	8	13	3 1/4	13	10	14	4 7/8	15	
20	10	11	2 1/8	11	7	12	0 1/4	12	6	13	0 1/4	13	6 3/4	14	1 1/2	14	9	15	4 3/8	16		16	8
22	11	12	3 5/8	12	8 7/8	13	2 3/8	13	9	14	3 3/8	14	11	15	6 1/8	16	2 5/8	16	10 1/8	17	7 1/4	18	4
24	12	13	5	13	10 3/8	14	5	15		15	7 1/2	16	3 3/8	16	11 5/8	17	8 1/4	18	5 1/4	19	2 3/4	20	
26	13	14	6 1/2	15	0 5/8	15	7 1/2	16	3	16	11	17	7 5/8	18	4 5/8	19	2	19	11 3/4	20	9 3/4	21	8
28	14	15	7 3/4	16	2 7/8	16	10	17	6	18	2 3/8	19		19	9 5/8	20	7 3/4	21	6 1/8	22	5	23	4
30	15	16	9 1/2	17	4 3/8	18	0 1/4	18	9	19	6 1/4	20	4 1/2	21	2 1/2	22	1 3/8	23	0 5/8	24	0 1/2	25	
32	16	17	10 5/8	18	6 1/4	19	2 3/8	20		20	10	21	8 1/4	22	7 1/8	23	7	24	7	25	7 3/8	26	8
34	17	19		19	8 1/8	20	5 1/2	21	3	22	1 1/2	23	0 1/4	24	0 1/2	25	0 3/8	26	1 1/2	27	2 3/4	28	4
36	18	20	1 3/8	20	10	21	7 3/8	22	6	23	5 1/8	24	5	25	5 1/4	26	6 1/8	27	7 1/8	28	9 3/8	30	
38	19	21	2 1/4	22		22	10	23	9	24	8 3/8	25	9 1/4	26	10 1/4	28	0 1/4	29	1 3/8	30	5	31	8
40	20	22	4 3/8	23	1 7/8	24	0 1/2	25		26	0 3/8	27	1 3/8	28	3 1/2	29	5 1/4	30	8 3/8	32	0 1/2	33	4
42	21	23	5 1/4	24	3 3/8	25	2 1/2	26	3	27	4	28	5 1/2	29	8 3/8	30	11 1/4	32	3 3/8	33	7 1/8	35	
44	22	24	7 1/8	25	5 3/8	26	5 1/4	27		28	7 3/8	29	10 1/4	31	1 3/8	32	5 1/2	33	9 3/8	35	2 3/8	36	8
46	23	25	8 5/8	26	7 1/8	27	7 3/4	28	9	29	11 1/4	31	2 1/4	32	6 3/8	33	11	35	4 1/2	36	9 7/8	38	4
48	24	26	10	27	9 3/8	28	10 1/2	30		31	2 7/8	32	6 3/4	33	11 1/4	35	4 1/2	36	10 1/2	38	5	40	
50	25	27	11 1/4	28	11 1/4	30	0 1/2	31	3	32	6 1/4	33	11	35	4 1/4	36	10 1/4	38	5	40	0 1/4	41	8

PRACTICAL TREATISE ON THE STEEL SQUARE.

VOL. II.

The student will be expected to read carefully these papers before doing any work. His name and address will require to be given on each page. He will be expected to write up the questions in a neat and intelligent manner, using his own style and language, representing the answers in such a manner as will be intelligible—make all drawings as clear as possible, and wherever they can be done render them in India ink. Let each answer be original, do not copy either from the instruction paper nor from any other source. The paper used may be of any kind, provided that it is clean and durable. Do not attempt an answer until you have thoroughly grasped the subject.

QUESTIONS.

1. Give description of "steel square" from Augusta, Maine.

2. Give some examples of how this square may be used.

3. Give description of color and coating of several steel squares, and what may be termed "the best."

4. Give description and sketch how to find by use of square, the cuts for each side of a roof having a box 12 inches square set on the ridge of roof.

5. Show by sketch and describe how to determine by a steel square the result of any number —for example, 6 multiplied by the sine 45°.

6. When the rise and seat of the corner posts are given of any rectangular framework which slopes alike on all four sides, show how to find the cuts for the ends of the corner posts, and the blade of the bevel to be applied to the two faces adjoining to the ridge line.

7. When the run and rise of a common roof are given, and we wish to place upon it a perpendicular square pipe to stand upon the roof diamond-shaped, show how by the steel square to find the cuts for the bottom end of the pipe, and the blade of the bevel to be applied to the two faces adjoining the lowermost vertical edge.

8. Suppose we wish to cut an opening in a roof for a round pipe or a tile, so that the pipe or tile will stand vertical through the opening, show by sketch how the exact form of the opening may be obtained.

9. Describe how by use of a steel square the size of a pulley that would be required to replace one in use, if speed is reduced or increased.

10. When the pitch of cogs and diameter of a wheel are given, show how by use of steel square to find the number of cogs in wheel.

11. When the diameter of a circle is given, show how to find the side of a square of equal area, by use of the steel square.

12. Show how by use of steel square to find the number of square yards in a given area.

13. Show how by use of steel square, to determine the circumference of a circle when the diameter is given.

14. When the area and diameter of any circle is known, show how the area due to any other diameter, or a diameter due to any other area, may be determined.

15. Give description and sketch showing the advantage of the steel square, in determining the proper depth of "core-boxes."

16. Show how to find the diagonal of a square or parallelogram, by use of the square.

17. Show how to find the circumference of an ellipse or oval, by use of the square.

18. Show how to find the side of the greatest square which may be inscribed within a circle, by use of the square.

19. Show how to inscribe three small circles within a large circle of given diameter, set to 6½ inches on tongue and 14 inches on blade.

20. Show how to get the length of a hoop for a wooden tank by the steel square.

21. Show "arithmetically" how to find the length of hoop for same tank.

22. The proper angle for ordinary door and window sills is about one inch drop to the foot,

show method of finding this inclination by use of the steel square.

23. The arms of a straight horizontal lever are 8 and 12. A weight of 9 lbs. is suspended from the shorter arm, what weight will balance it on the longer arm, show by use of steel square.

24. Show how much power is required to support a weight of 4 lbs. on an incline of 5 in 30, by use of the steel square.

25. A body is weighed in a false balance and in one scale appears to be 9 oz. and in the other 12 oz. What is its true weight? Show this firstly by arithmetic and secondly by use of the steel square.

26. A spout is 20 inches square, what is the diameter of a cylindrical one with the same area of cross-section? Show how to obtain by use of the steel square.

27. Show how by use of the steel square the length and angles of a brace of irregular run or any run, may be obtained.

28. Show by description and sketch how to give a square stick an octagonal shape where fractions of an inch are involved.

29. Show how to divide a board 7 inches wide into four equal parts, by use of "the rule."

30. Show how to square a board by use of "the rule."

31. Show how to strike a circle and have nothing but a rule.

32. Show by sketch and description how to find the distance across a body of water, without crossing same.

33. Show by sketch and description how a tree or any inaccessible height can be measured.

34. Show by sketch and description how to obtain the proper angles and bevels of trestles.

35. Show by sketch the end of a framed trestle with posts on the same inclination, also the braces, one framed in the angles and the other spiked on.

36. Show by sketch and describe how to get the bevel cut on a square stick, say 4″x4″.

37. Give description how to obtain the lengths and cuts of hip rafters on a pitch of 45°, by the use of the steel square.

38. Give description and sketch showing how to obtain the side cut on hip or valley rafter, by use of square.

39. Give plan of the valley rafter as laid off for cutting bevels.

40. Give sketch showing position where ridges meet.

41. Give description and sketches showing the valley rafter in its proper position on the wall-plats, and how to find the hypothenuse or line of rafter supposing that the rise is 9 inches to the foot run, by use of steel square.

42. Give description and sketch showing the method of obtaining the bevel on valley rafter, by use of the square.

43. Suppose the half width of a roof having a pitch of 45° degrees is 10 feet, and that an adjoining roof is one-third pitch, how many feet will it take to make an equal rise?

44. Describe how to frame a rafter against two ridge boards running at right angles.

45. When the pitches are the same on all sides of a roof and the building is square, at what angle of degrees do the hips or valleys run in from the corners?

46. Give description and sketches showing how to find the top cuts of left and right jack-rafters on a roof plan with the one-third pitch on the main part, with a half pitch gable.

47. In connection with an uneven-pitched roof, where a projecting cornice is desired, with plancer, at what point will the valley rest, and explain how much the plate on the steeper pitch will be raised above that of the lower pitch.

48. Give sketch and description showing how to find, by use of two "squares," the runs of common rafters, runs of jack rafters, short valley and long valley, where the rises in the roof are of different heights.

49. Give description and sketch showing how to get the bevel of the top edge of the jack rafter, by use of the square.

50. Give description and sketch showing how to get the bevel for the side of the purlin to fit against the hip rafter, by use of the square.

51. Give description and sketch showing how to get edge bevel of purlin, by use of the square.

52. Give description and sketch showing how to cut "jacks" for curved roofs.

53. Give description and sketch showing how to get hip rafters for curved roofs, without using the square for the purpose.

54. Give description and sketch showing how to obtain the lateral curve of valley rafter.

55. Give description and sketch showing how to get the side bevels and lengths for jacks in a hipped roof.

56. Give description and sketch showing how to get bevel or backing of "hips."

57. Give description and sketch showing how to lay out an octagon bay window.

58. Give description and sketch showing how the framing of an octagon roof of tower or spire is formed when it intersects another roof.

59. Give description and sketch showing how the pitch of a tower roof may be obtained by use of the square.

60. Give description and sketch showing the method of laying off the lines for an octagonal roof having curved rafters.

61. Give description and sketch showing the method of obtaining the curves for hip and jack rafters of an octagonal roof.

62. Give sketches showing the plan, elevation and section in the construction of an octagonal dormer roof.

63. Give sketches of three kinds of "hoppers," i. e., triangular, square and hexagonal.

64. Describe the geometrical problems involved in these cases.

65. Give description and sketches showing how all the lines and cuts may be obtained by use of the square, in the construction of these hoppers.

66. Give description and sketch showing how to find the side cut and miter of large hoppers.

67. Give description and sketch showing another method for obtaining same, taken from the old "American Builder."

68. Give description and sketch showing how to represent the elevation of a box, the sides of which have a slope of 45°.

69. Give description and sketches showing how the miters and cuts of a "hopper" may be obtained by use of the square.

70. Give description and sketch showing another method of finding the miter, and the angle of co-pitch standing at an angle of 90° with the given pitch.

71. Give description and sketches, showing how to obtain the bevels and cuts for nearly all kinds of flared work or inclined framing as described by the late Robert Riddell.

72. Give description and sketches showing how to lay out the lines for every conceivable cut required in tapered framing, paneling or splayed

work of any kind when angles are thrown out of square (according to method accredited to Peter Nicholson and improved by the late Robert Riddell).

73. Give description and sketch showing how to divide a line of any length into any number of equal parts, by the steel square.

74. What scale is the most convenient in dividing a space of any great extent, and give an example?

75. Give description and sketch showing how by the steel square to find the diagonal of a square when one side of the square is given.

76. Give description and sketch showing how to get the diagonal of a square, the sides of which measure 10 feet 6 inches, by use of the steel square.

77. Give description and sketch that shows a construction of what may be termed "an attempt at squaring the circle"?

78. Give proof of the correctness of this solution by means of the steel square.

79. Give description of how the utility of the steel square may be applied to the measurement of any surface, or to find the capacity of anything round or square.

80. Give description and sketch showing how to obtain by the steel square the superficial contents of a board or other material that is not more than one inch thick, and 26 feet long and 6 inches wide.

81. Give description how to find solution of same by the right angle.

82. Give description how to find the measurement of a board 21 feet long and 19 inches wide, by steel square.

83. Give description how to find the surface measurement of a board 18 feet long and 10½ inches wide, by the use of the steel square.

84. Give description how to find the surface measurement of a board 18 feet long and 9 inches wide, by use of steel square.

85. Give description how to find the surface measurement of a board 29 feet long and 4 inches wide, by use of the steel square.

86. Give description of how to reduce surface measure to square yards by use of the steel square.

87. Give description of how to find the number of square yards in a floor 22 feet long and 15 feet wide, by aid of the steel square.

88. Give description of how to find the number of square yards of carpet that will cover a floor 18 feet long and 13 feet wide, by use of the steel square.

89. Give description of how to find the number of square yards in a floor which is 15 feet long and 11 feet wide, by use of the steel square.

90. Give description of how to find the number of square yards on the surface of a counter which is 10 feet long and 7½ feet wide, by use of the steel square.

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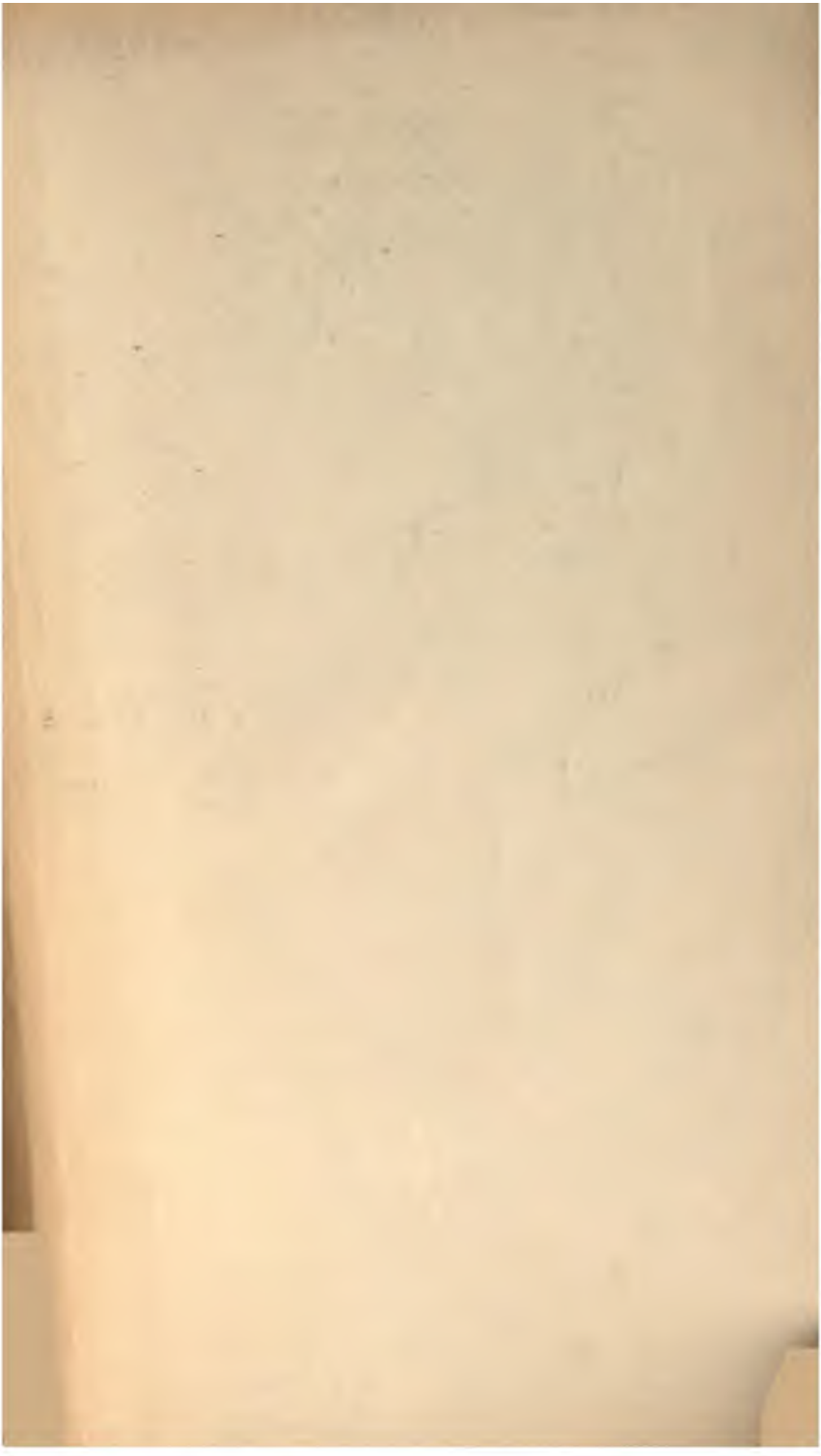

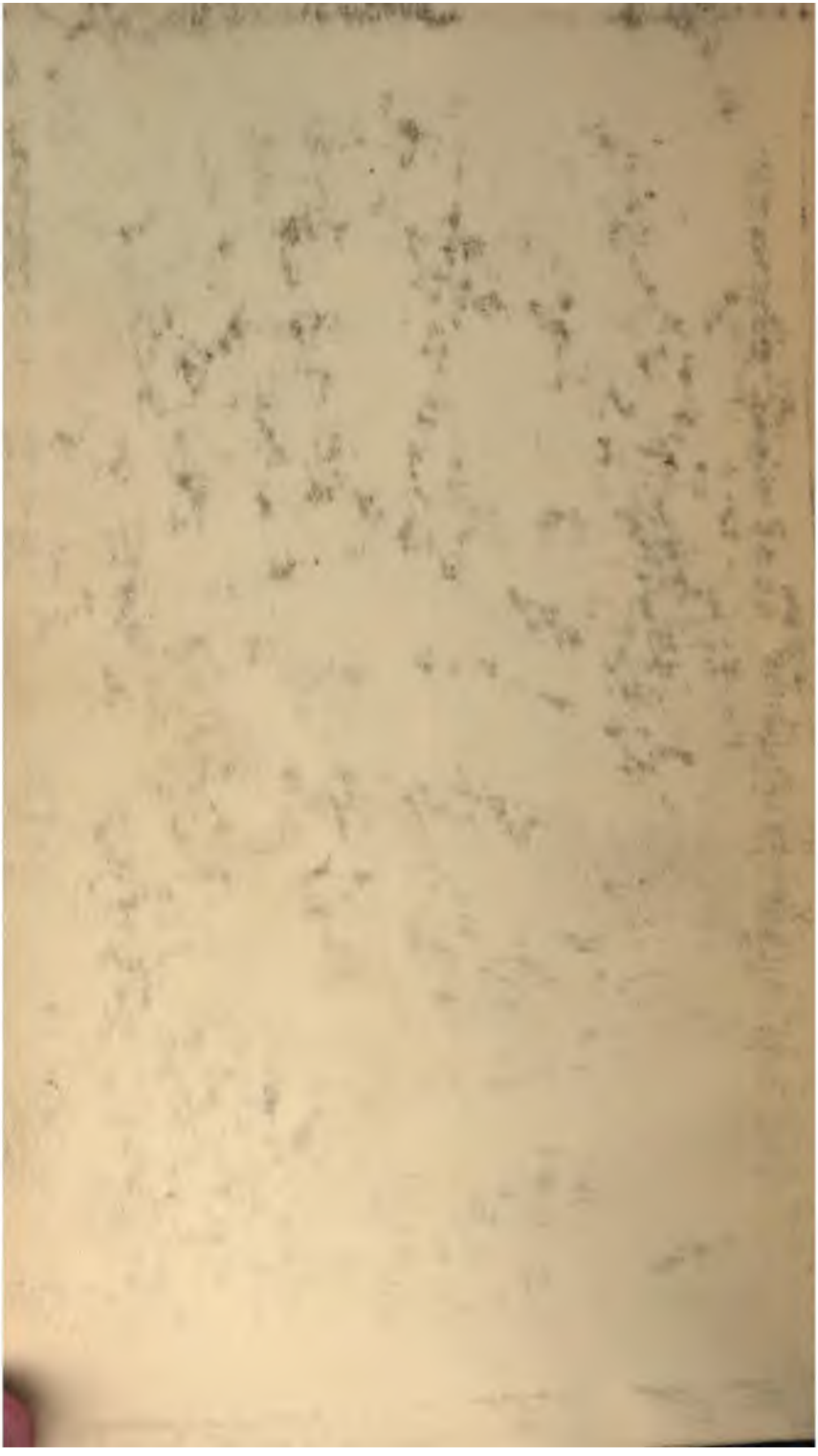

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